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(12) **United States Patent**
Ogihara

(10) **Patent No.: US 7,642,560 B2**
(45) **Date of Patent: Jan. 5, 2010**

(54) **COMPOSITE SEMICONDUCTOR LIGHT-EMITTING DEVICE**

(75) Inventor: **Mitsuhiko Ogihara**, Hachioji (JP)

(73) Assignee: **Oki Data Corporation**, Tokyo (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **11/534,688**

(22) Filed: **Sep. 25, 2006**

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US 2007/0069220 A1 Mar. 29, 2007

(30) **Foreign Application Priority Data**

Sep. 27, 2005 (JP) 2005-280822

(51) **Int. Cl.**
H01L 33/00 (2006.01)

(52) **U.S. Cl.** **257/90**; 257/89; 257/94; 257/E33.008; 257/E33.012; 257/E33.023; 257/E33.025; 257/E33.028

(58) **Field of Classification Search** 257/79, 257/89, 90, 94, E33.12, E33.008, E33.023, 257/E33.025, E33.028
See application file for complete search history.

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Primary Examiner—Kiesha L Rose
Assistant Examiner—Minchul Yang
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(57) **ABSTRACT**

A composite semiconductor light-emitting device includes a first semiconductor element portion made of a first semiconductor material and a second semiconductor element portion made of a second semiconductor material different from the first semiconductor material. The first semiconductor element portion has a first semiconductor layered structure, and the second semiconductor element portion has a second semiconductor layered structure. The first semiconductor element portion has a plurality of light-emitting regions that emit lights of different wavelengths. The second semiconductor element portion has at least one light-emitting region that emits light whose wavelength is different from the lights emitted by the light-emitting regions of the first semiconductor element portion. The light-emitting regions of the first semiconductor element portion and at least one light-emitting region of the second semiconductor element portion are electrically connected to each other.

27 Claims, 34 Drawing Sheets

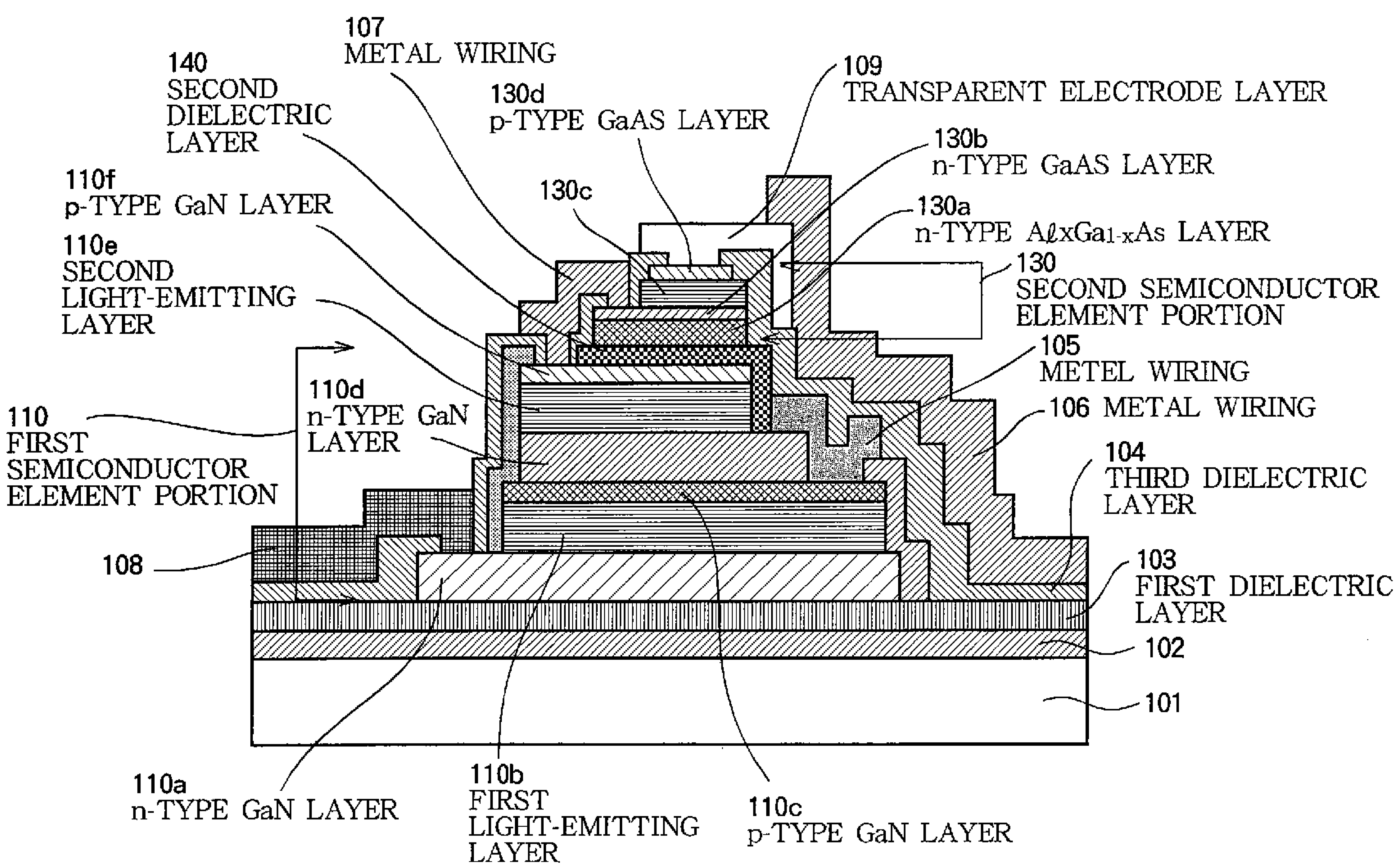

FIG. 1

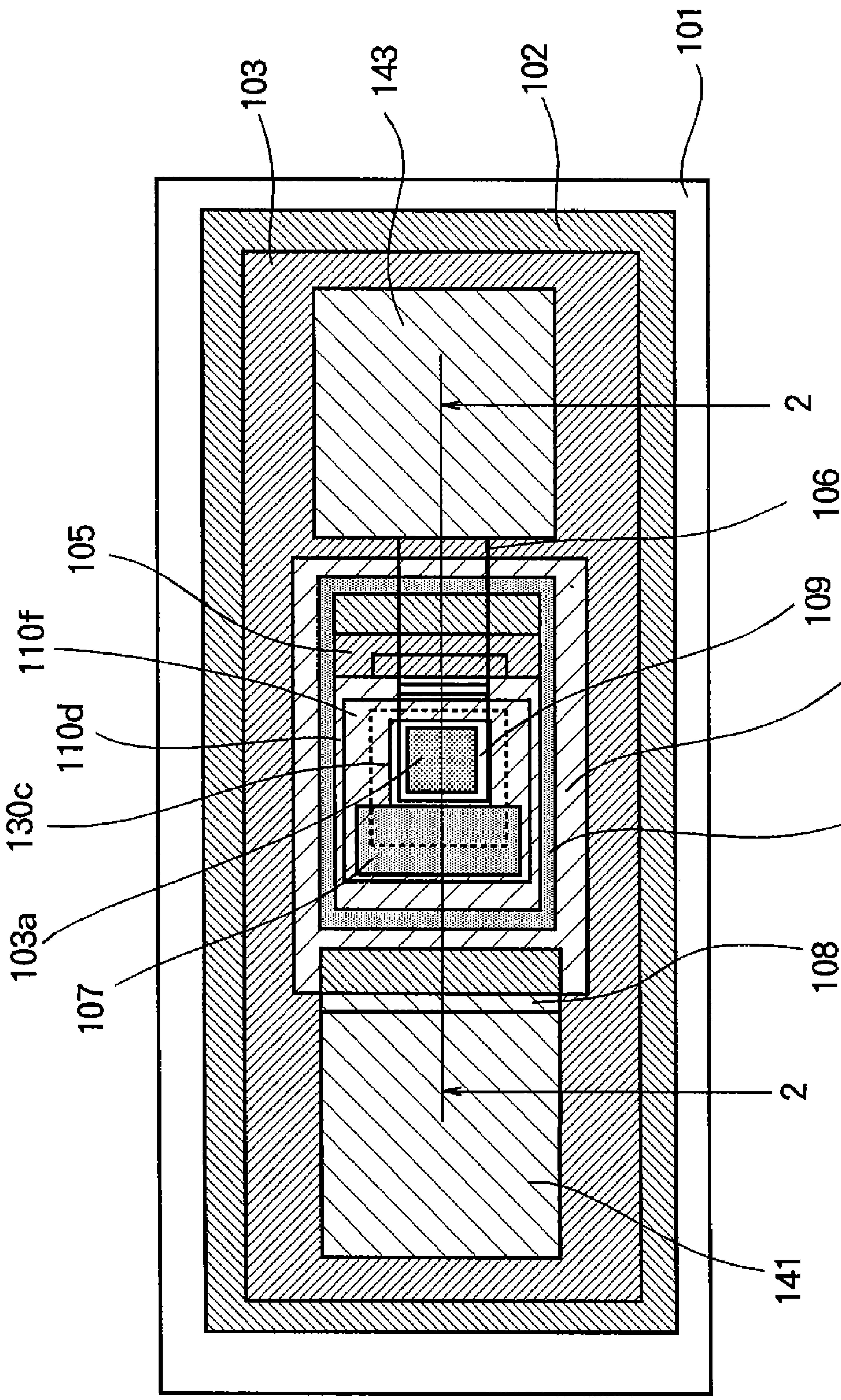
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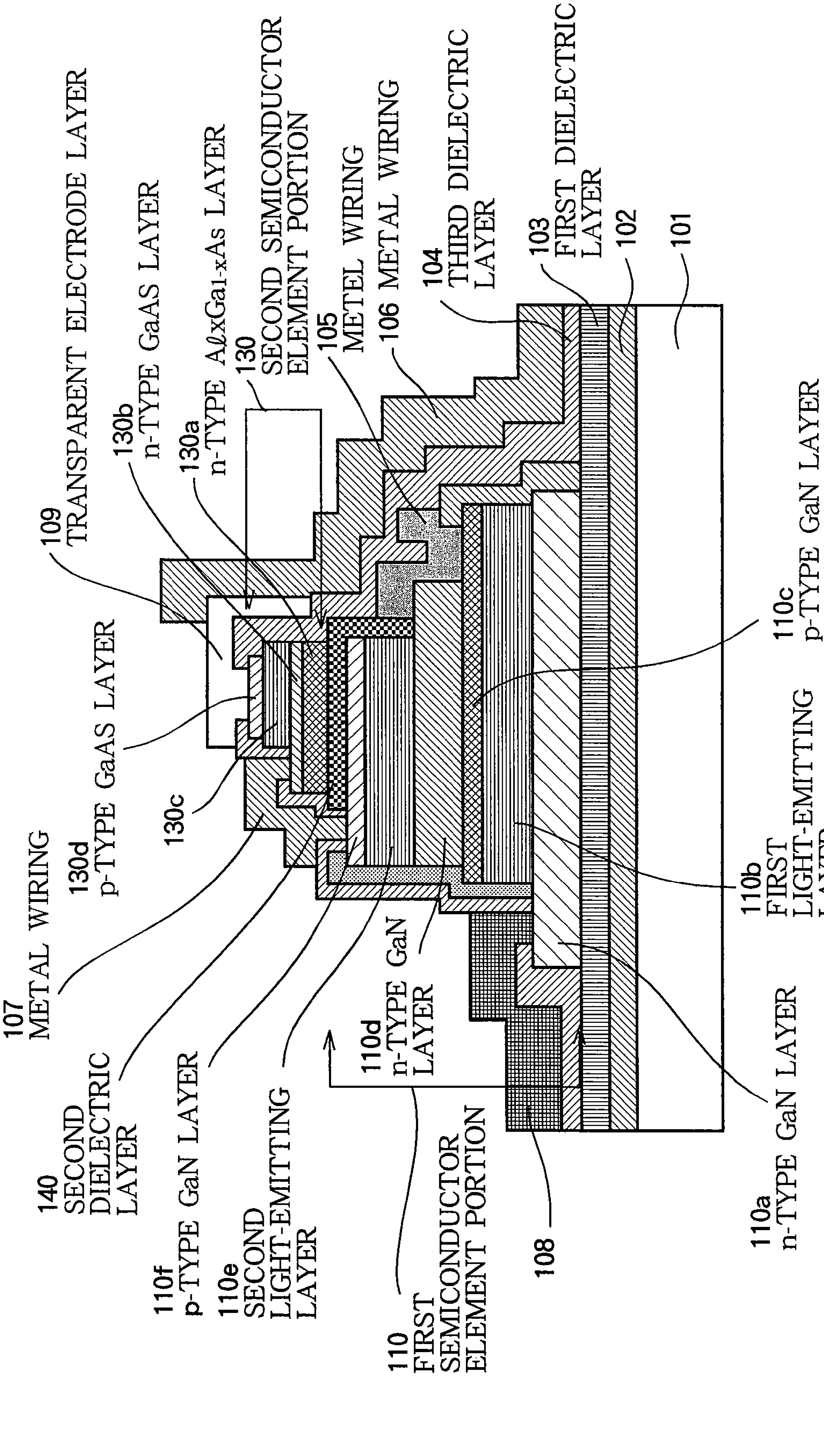
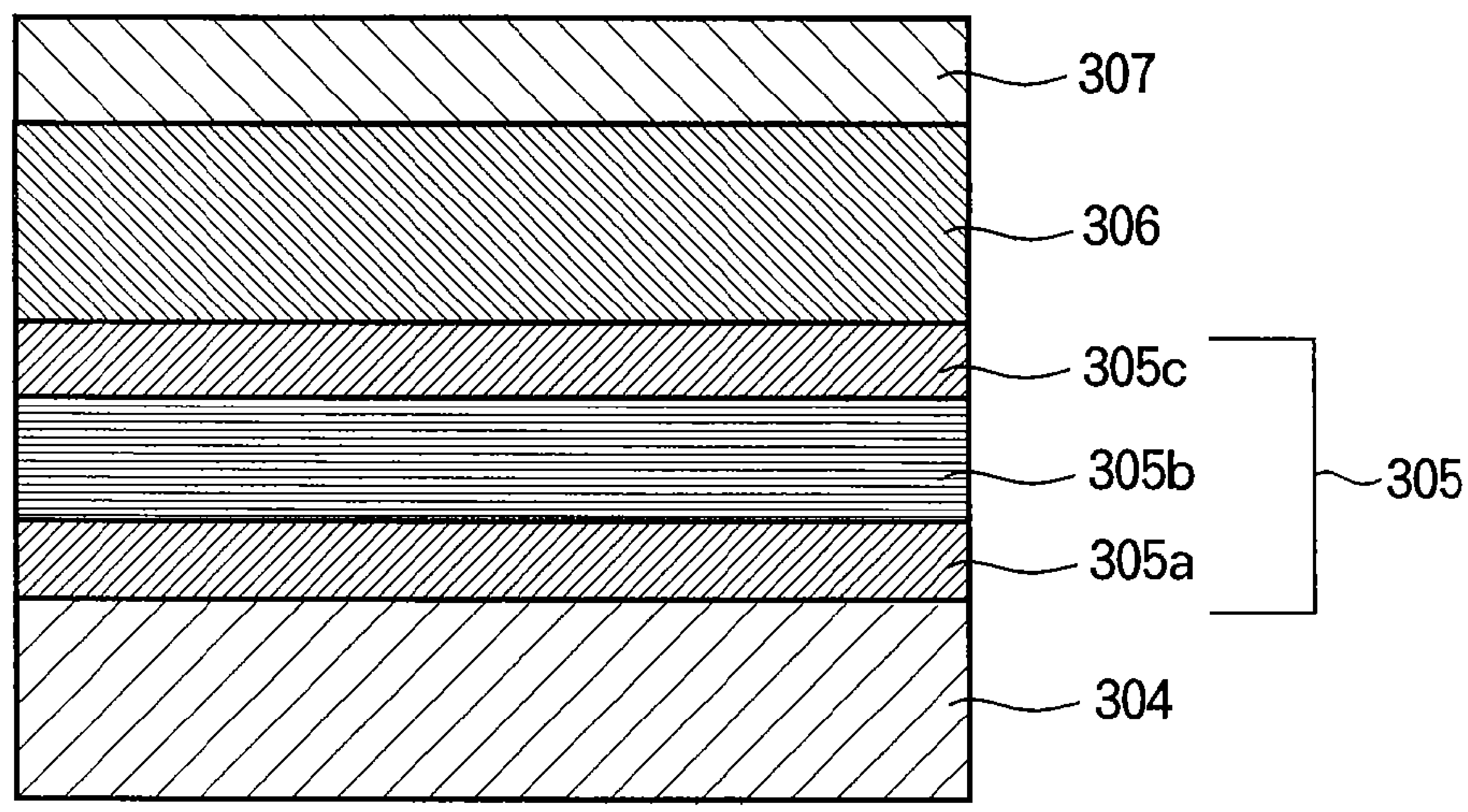
FIG.2



109 TRANSPARENT ELECTRODE LAYER
130b n-TYPE GaAS LAYER
130a n-TYPE AℓxGa1-xAs LAYER
130 SECOND SEMICONDUCTOR ELEMENT PORTION
105 METEL WIRING
106 METAL WIRING
104 THIRD DIELECTRIC LAYER
103 FIRST DIELECTRIC LAYER
102
101
p-TYPE GaAS LAYER
130c
130d p-TYPE GaAS LAYER
107 METAL WIRING
140 SECOND DIELECTRIC LAYER
110f p-TYPE GaN LAYER
110e SECOND LIGHT-EMITTING LAYER
110d n-TYPE GaN LAYER
110 FIRST SEMICONDUCTOR ELEMENT PORTION
108
110a n-TYPE GaN LAYER
110b FIRST LIGHT-EMITTING LAYER
110c p-TYPE GaN LAYER

FIG.3



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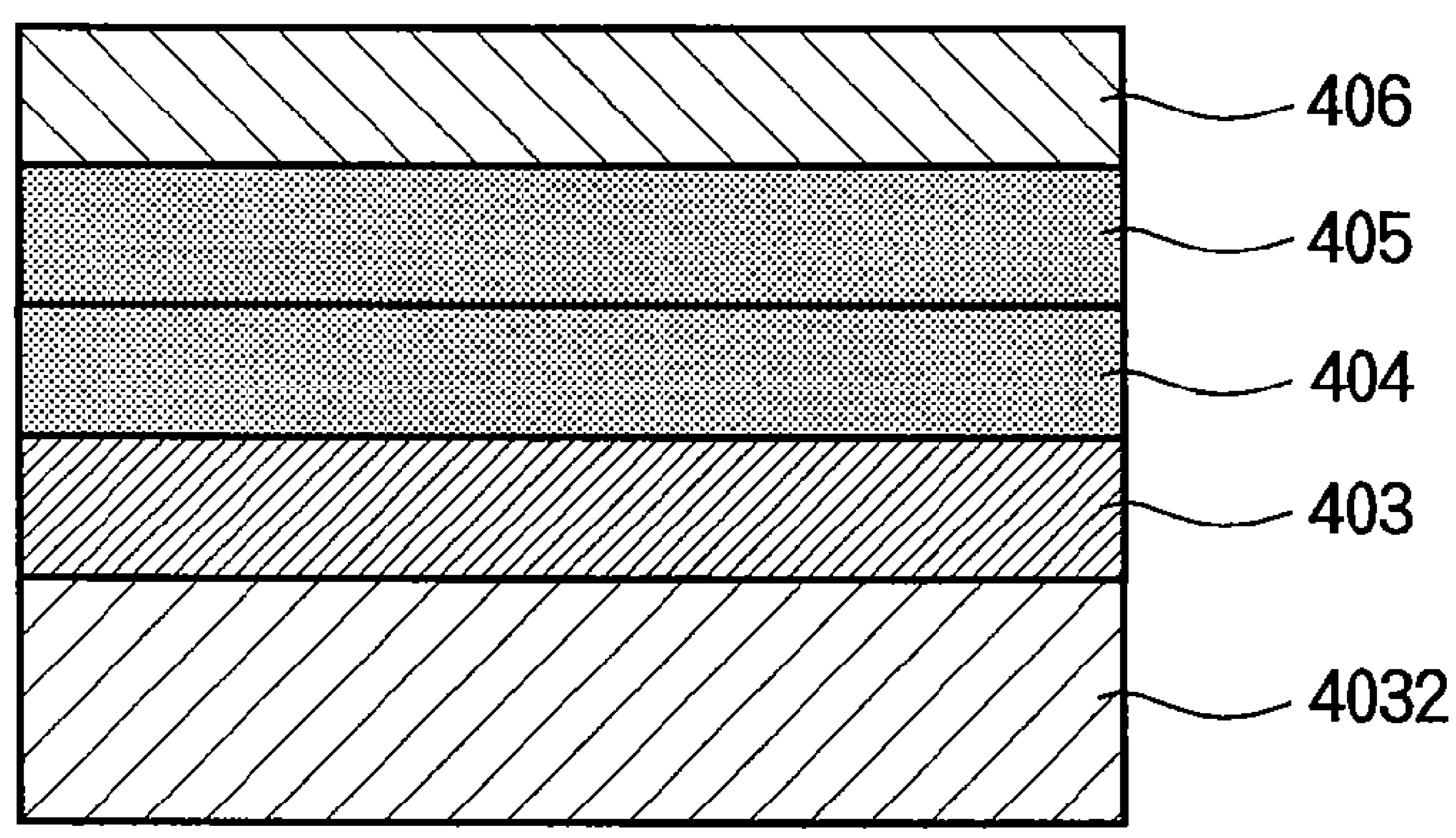

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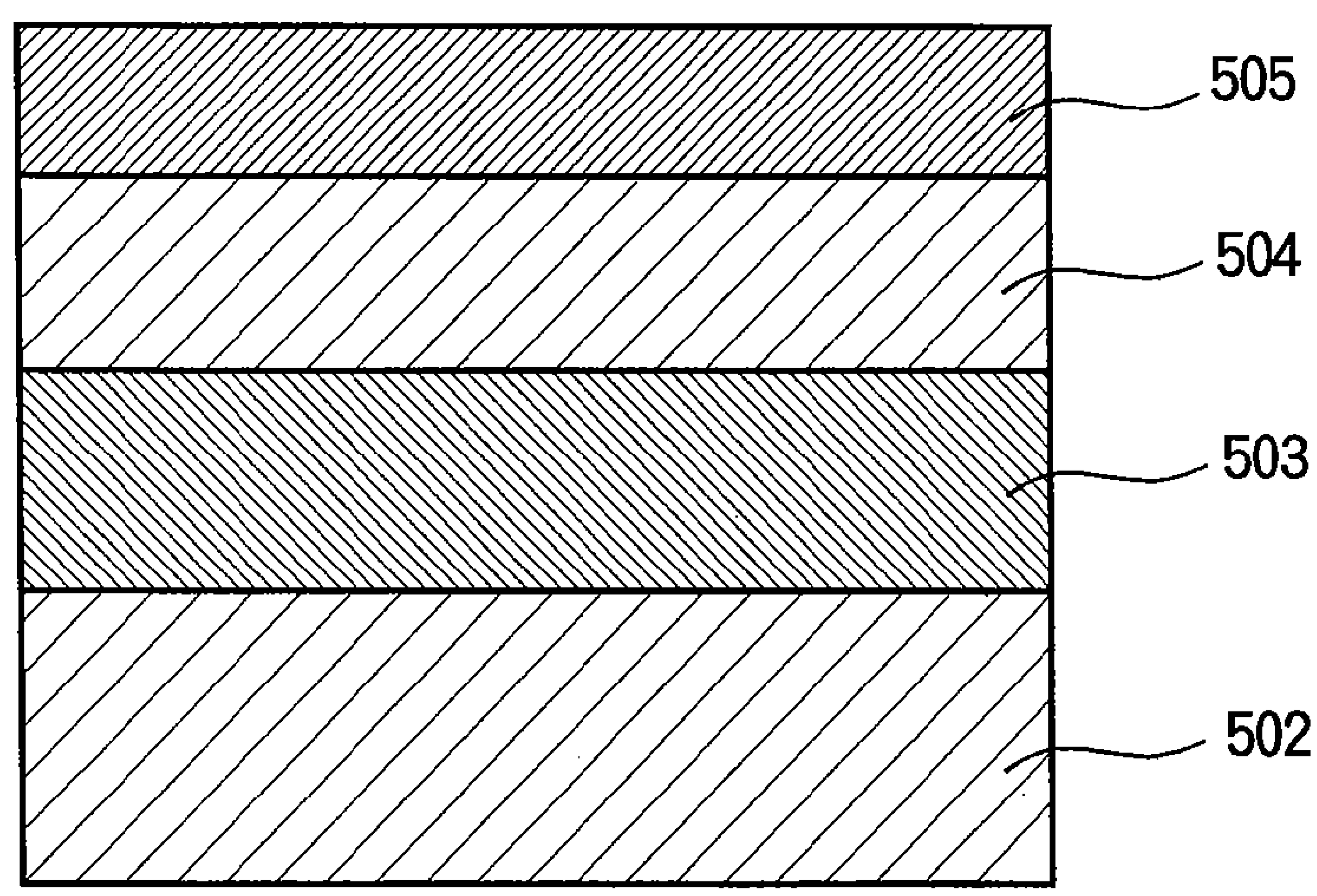
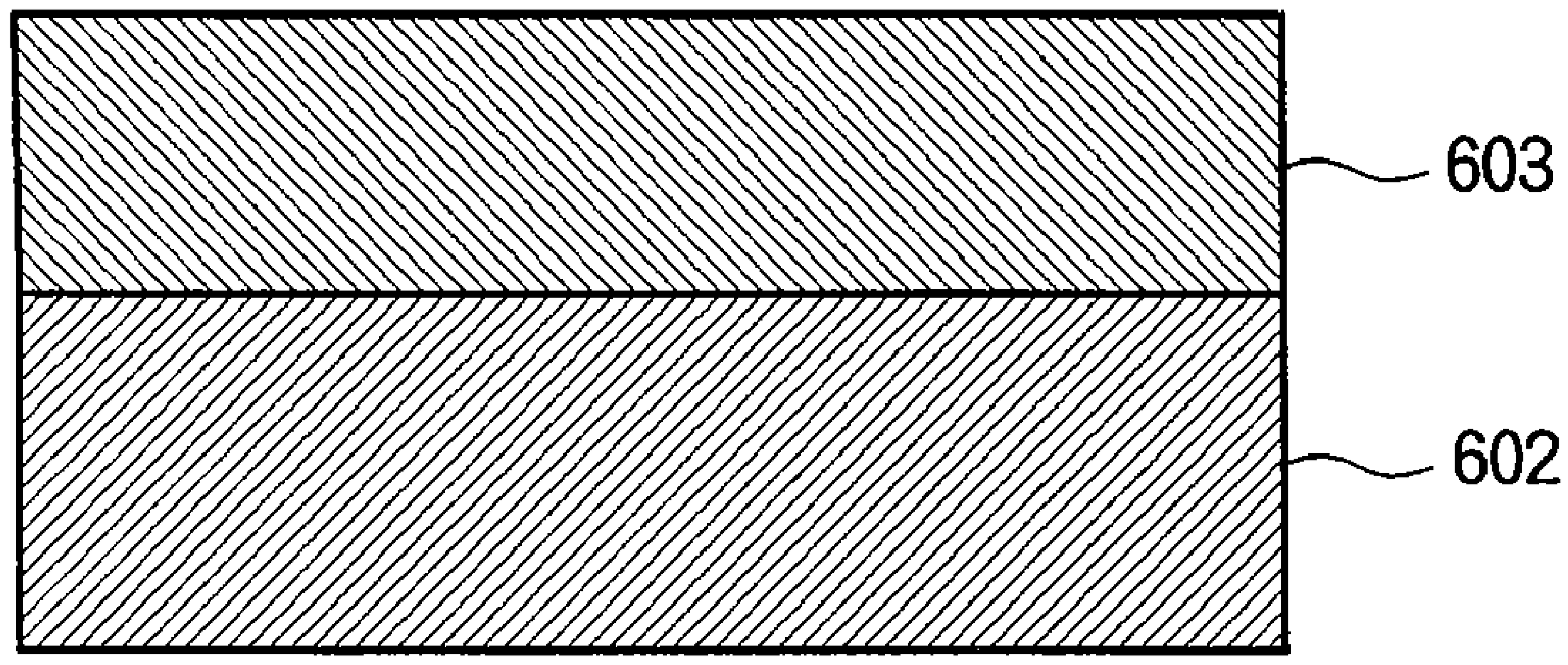


FIG.6



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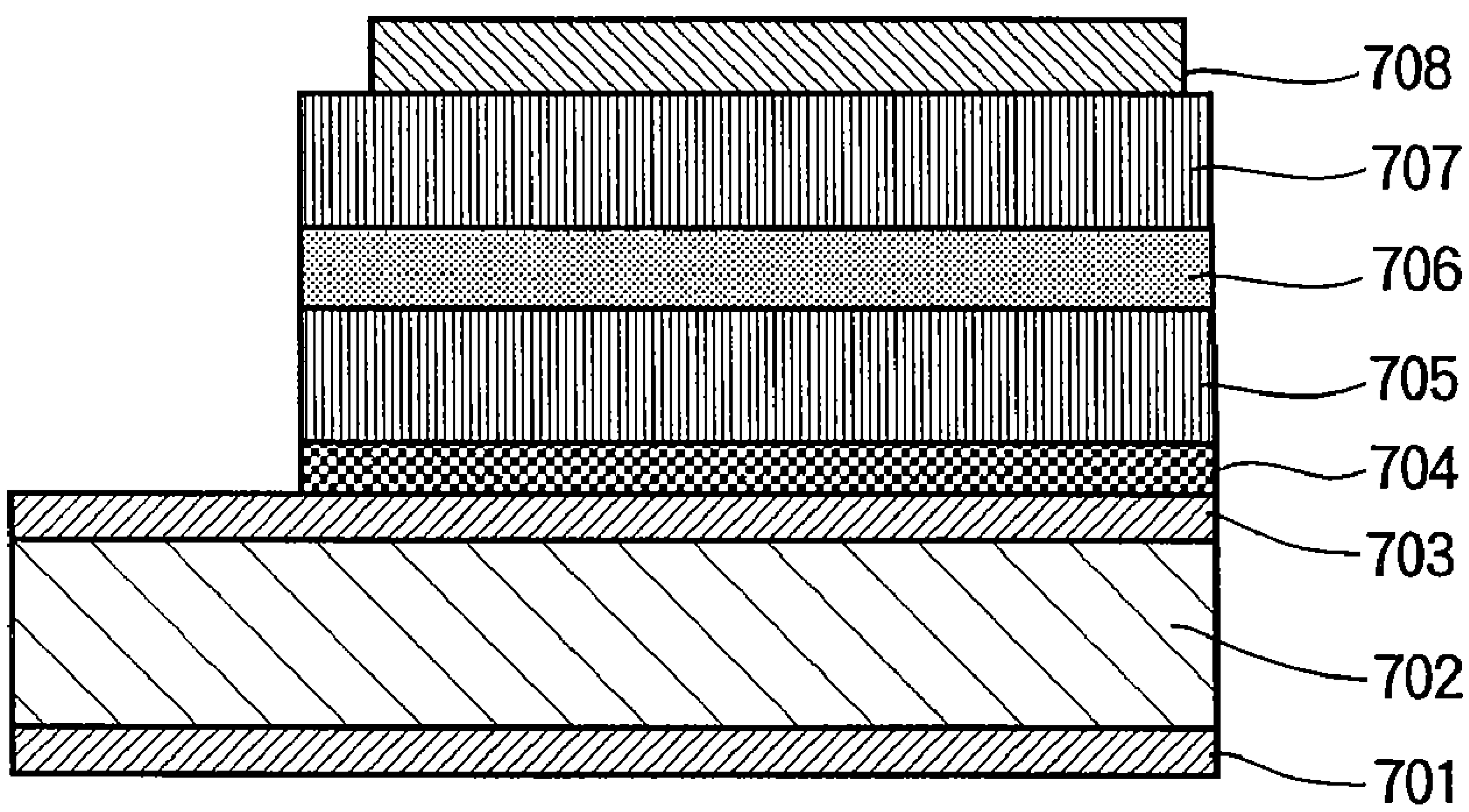

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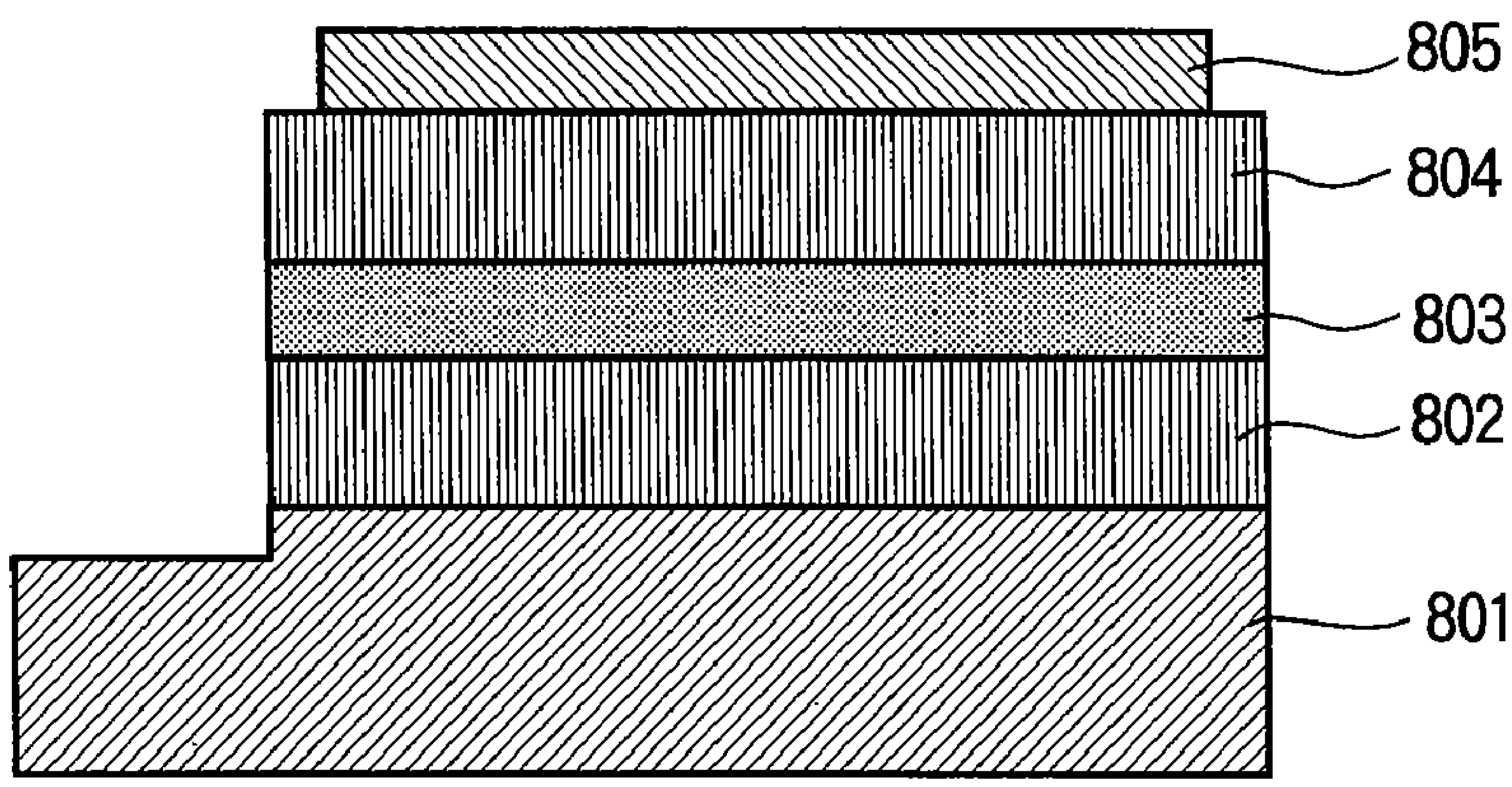

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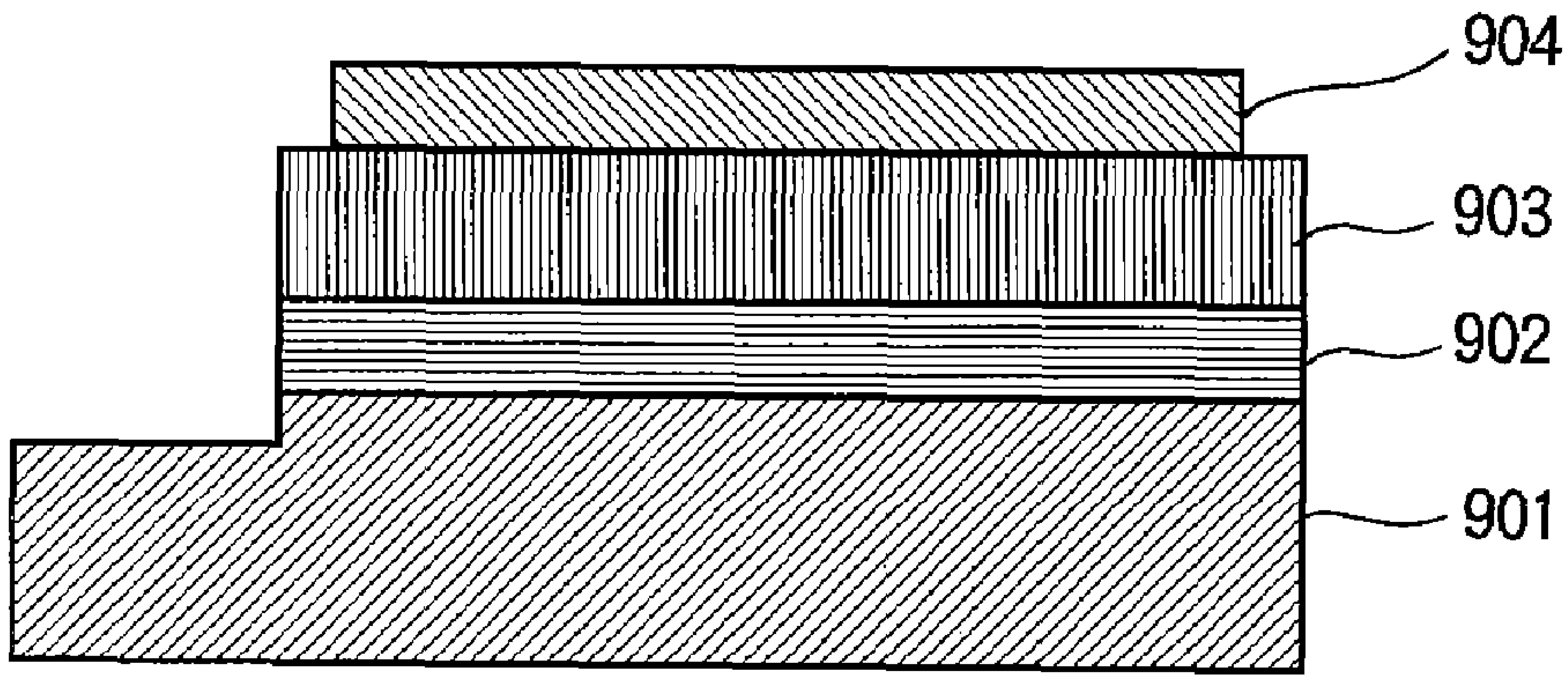

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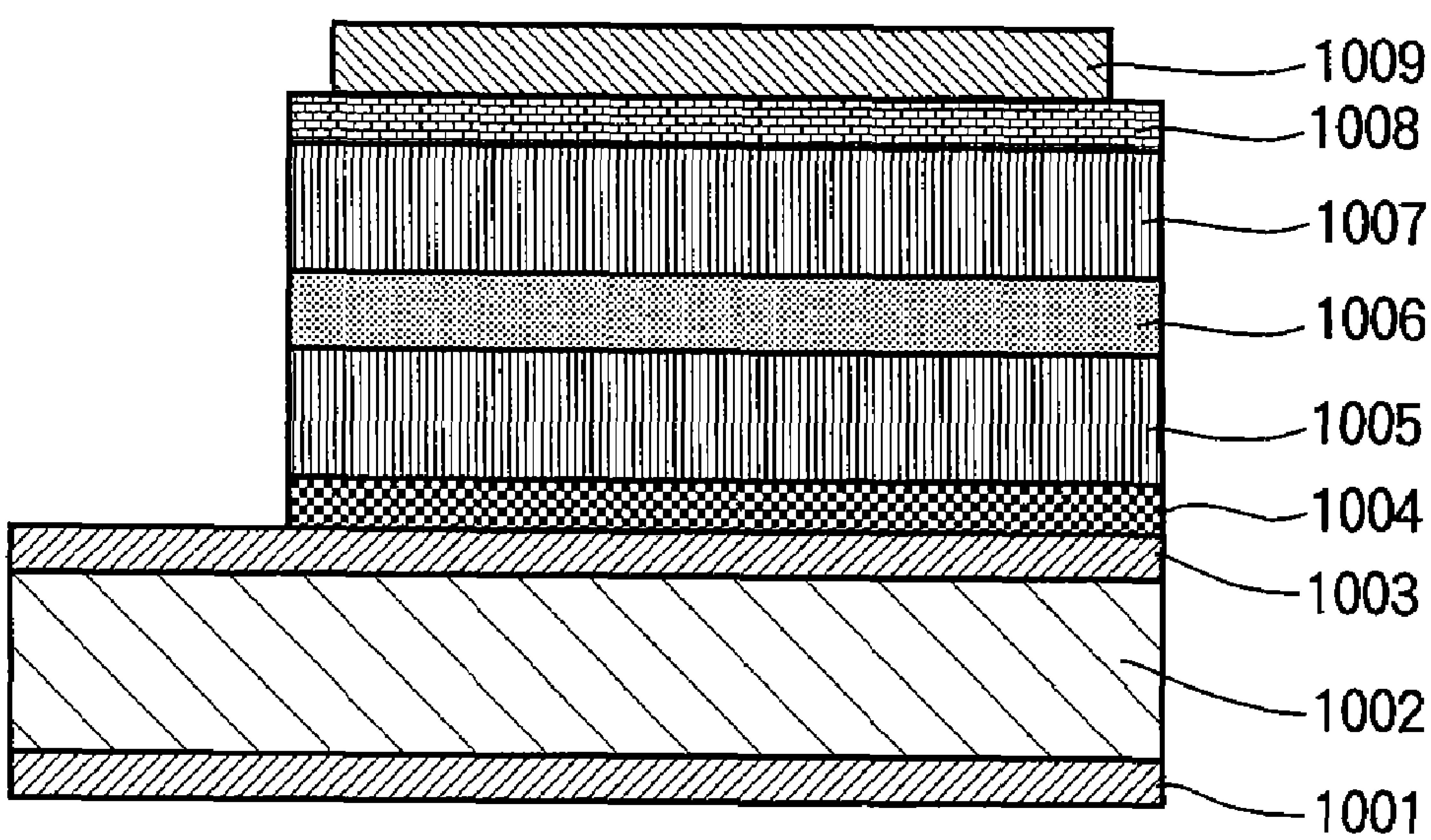

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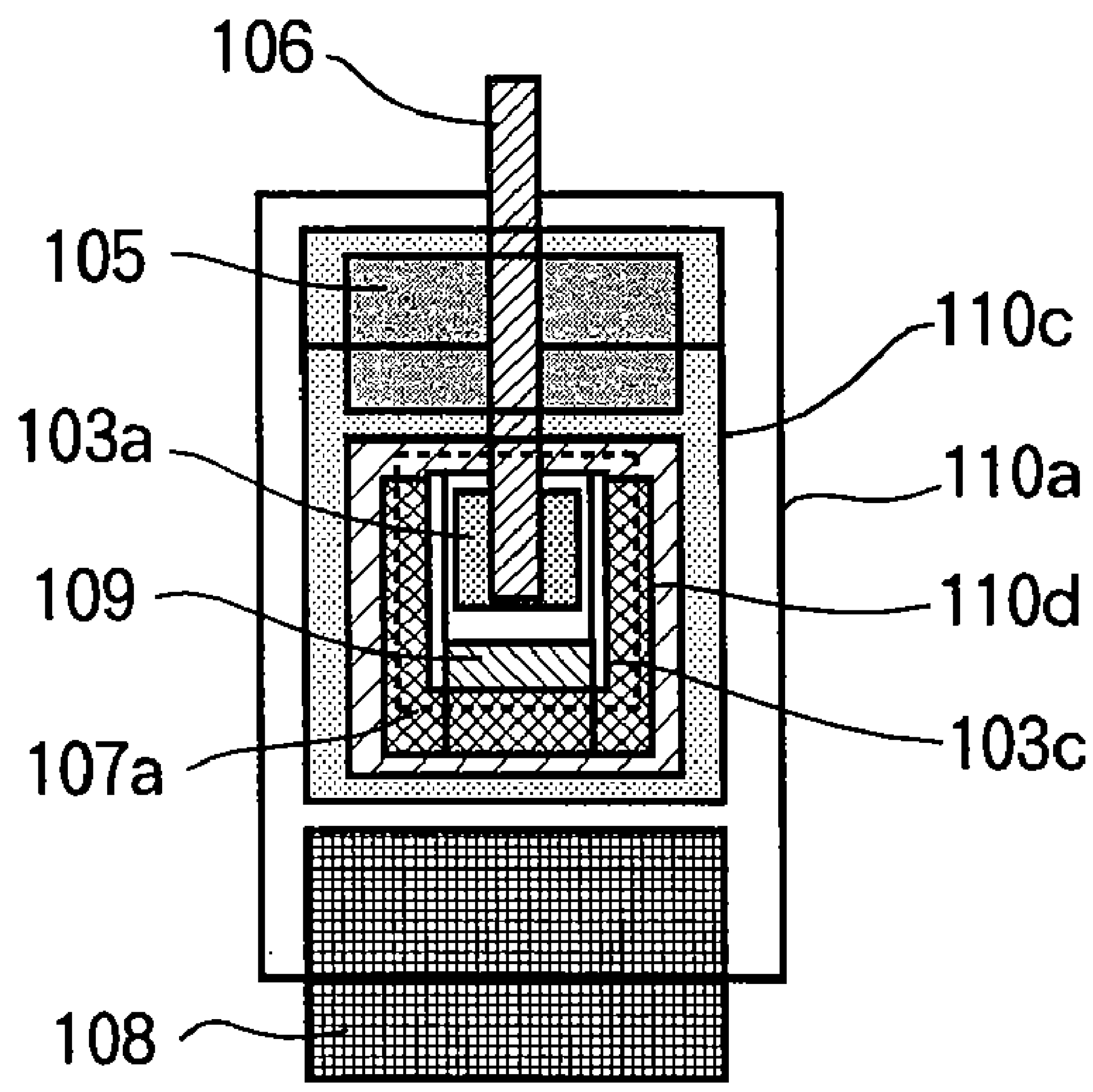
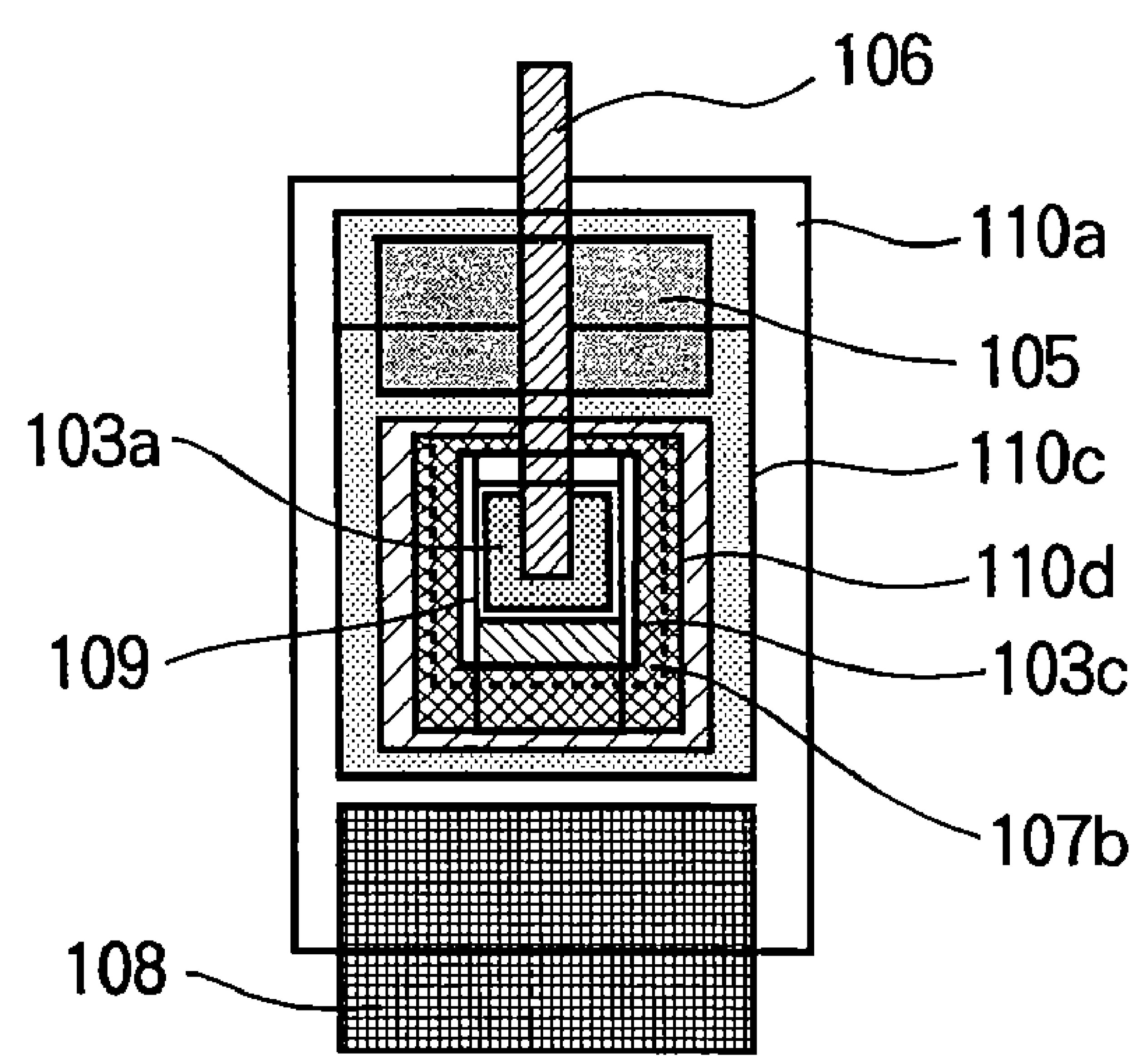


FIG12.



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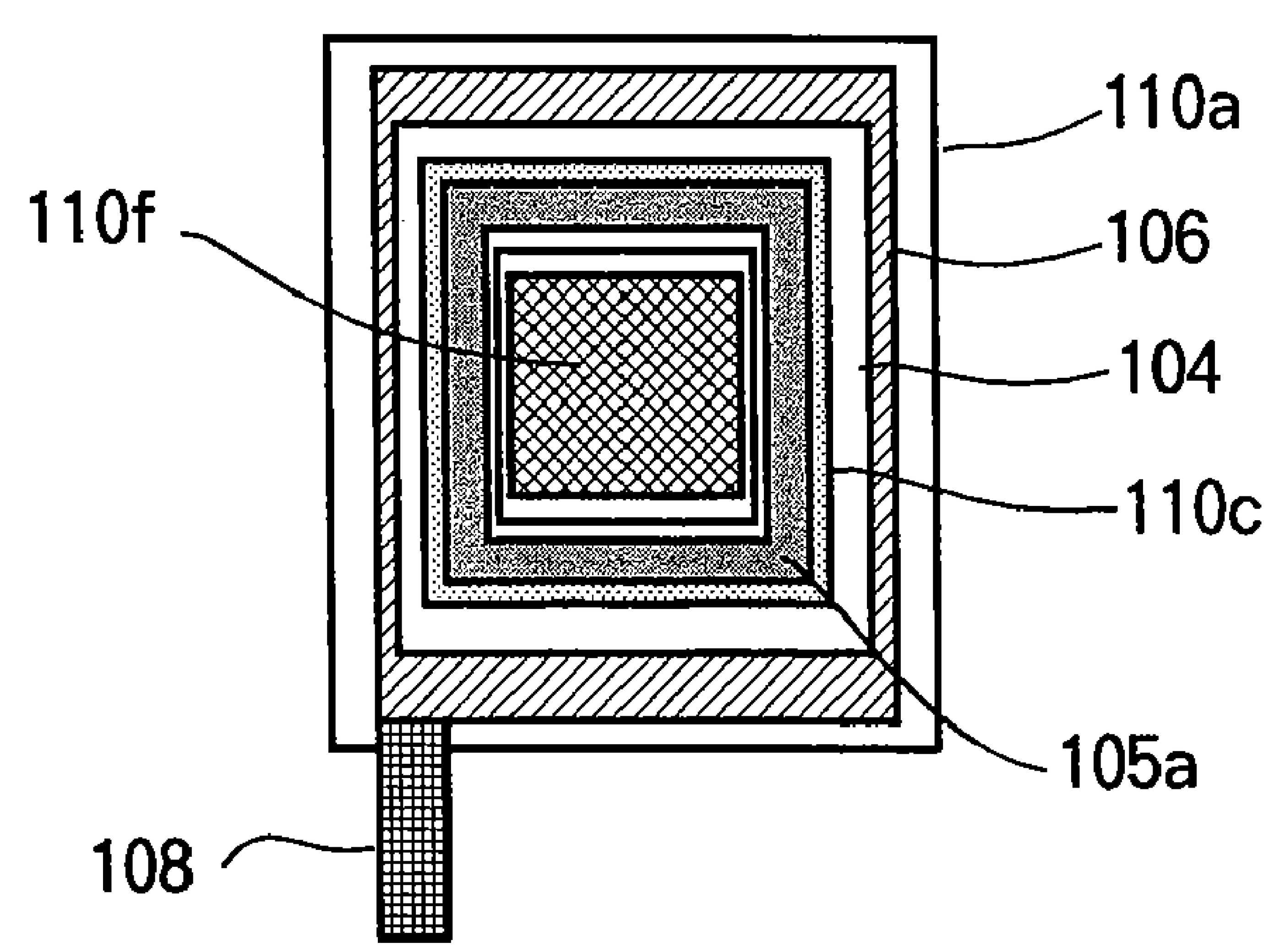
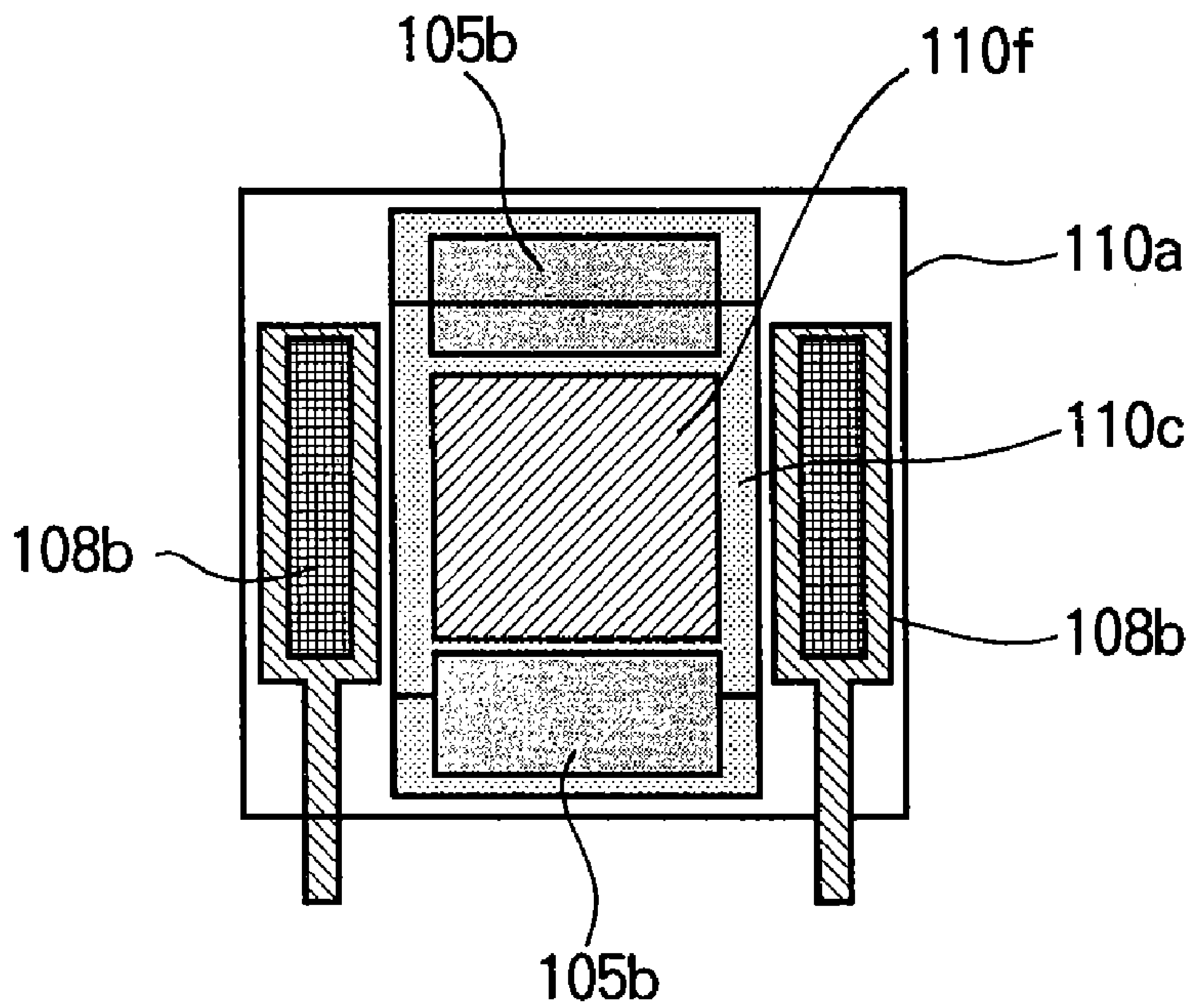


FIG. 14



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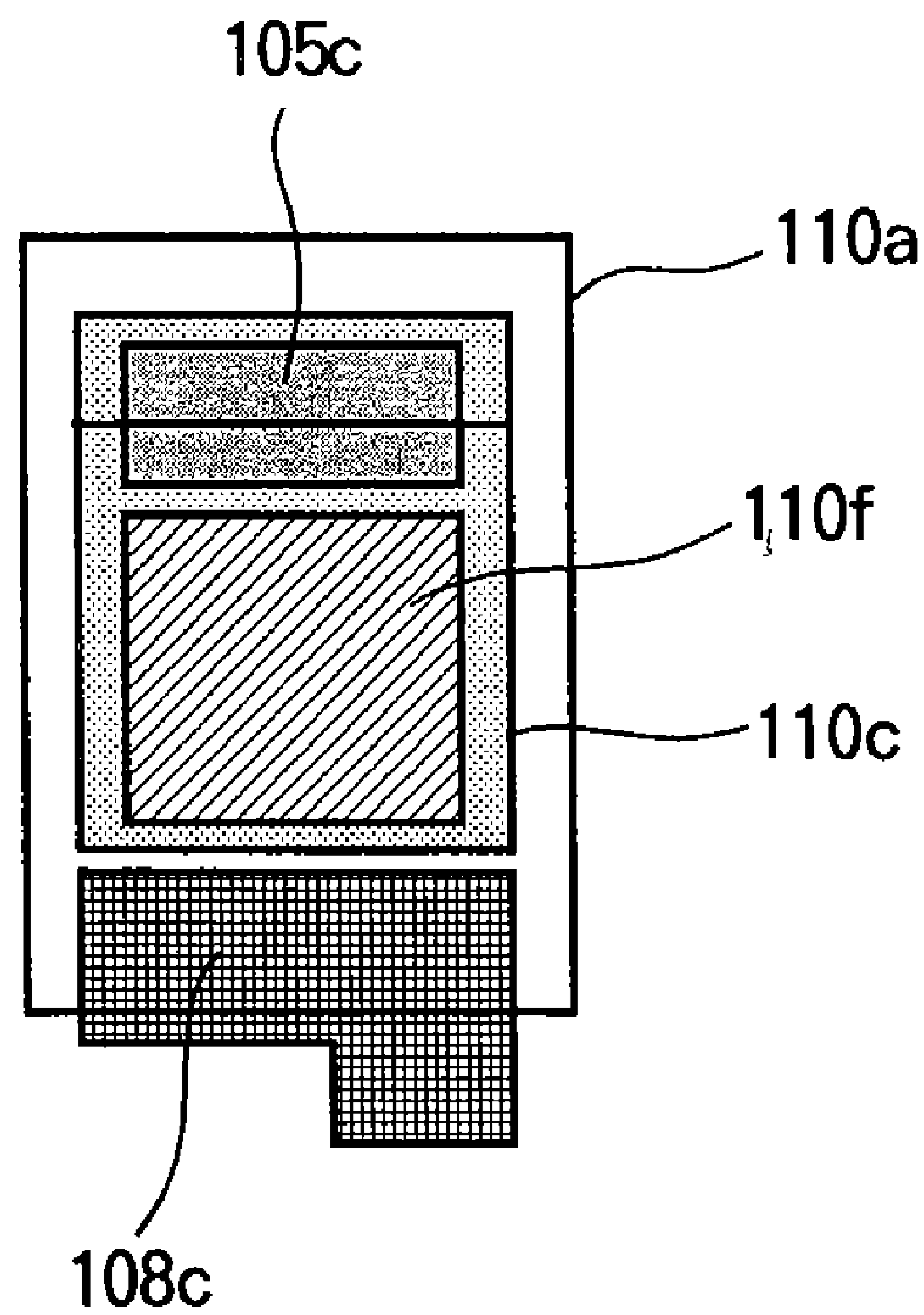

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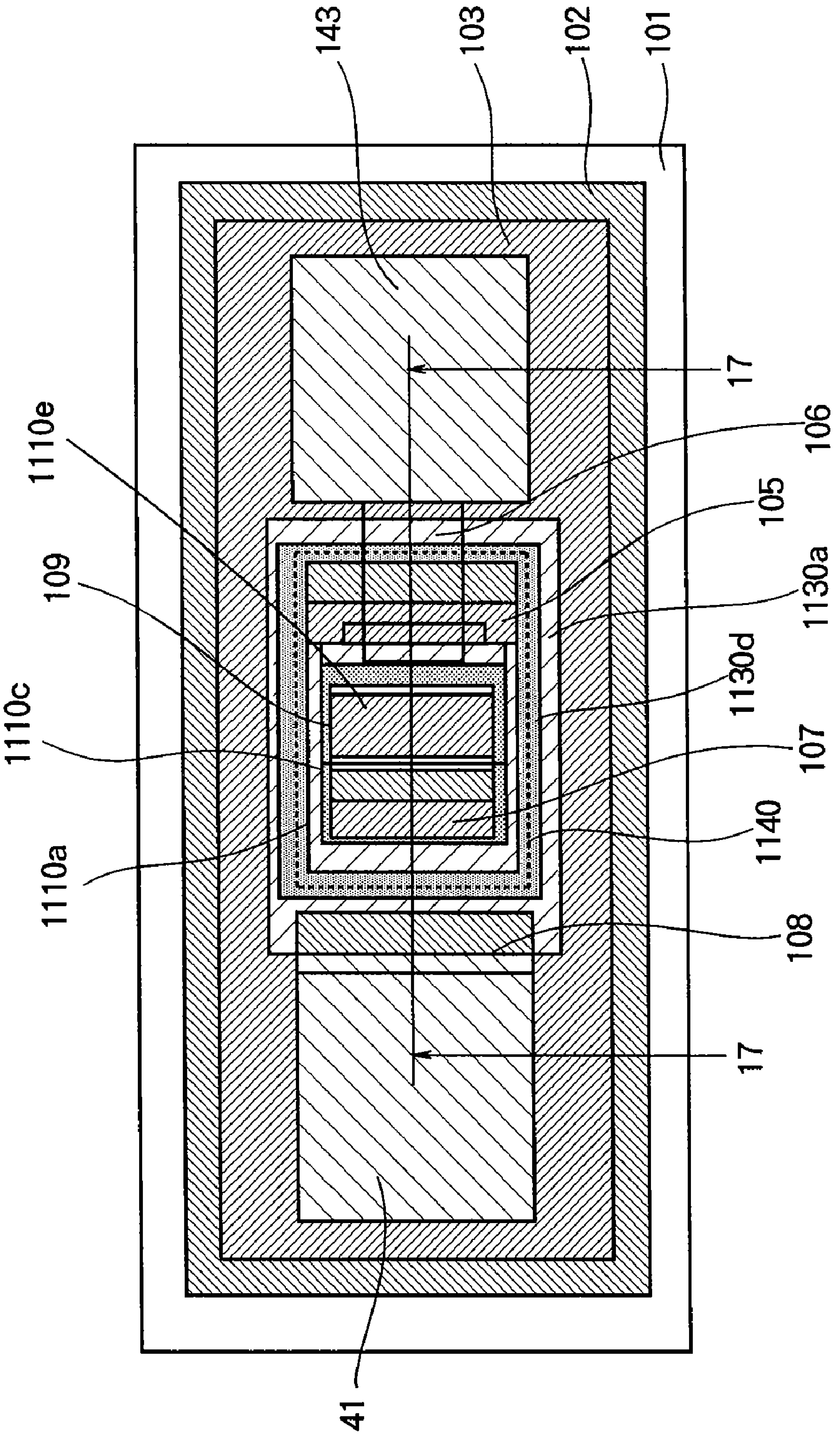
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FIG.17

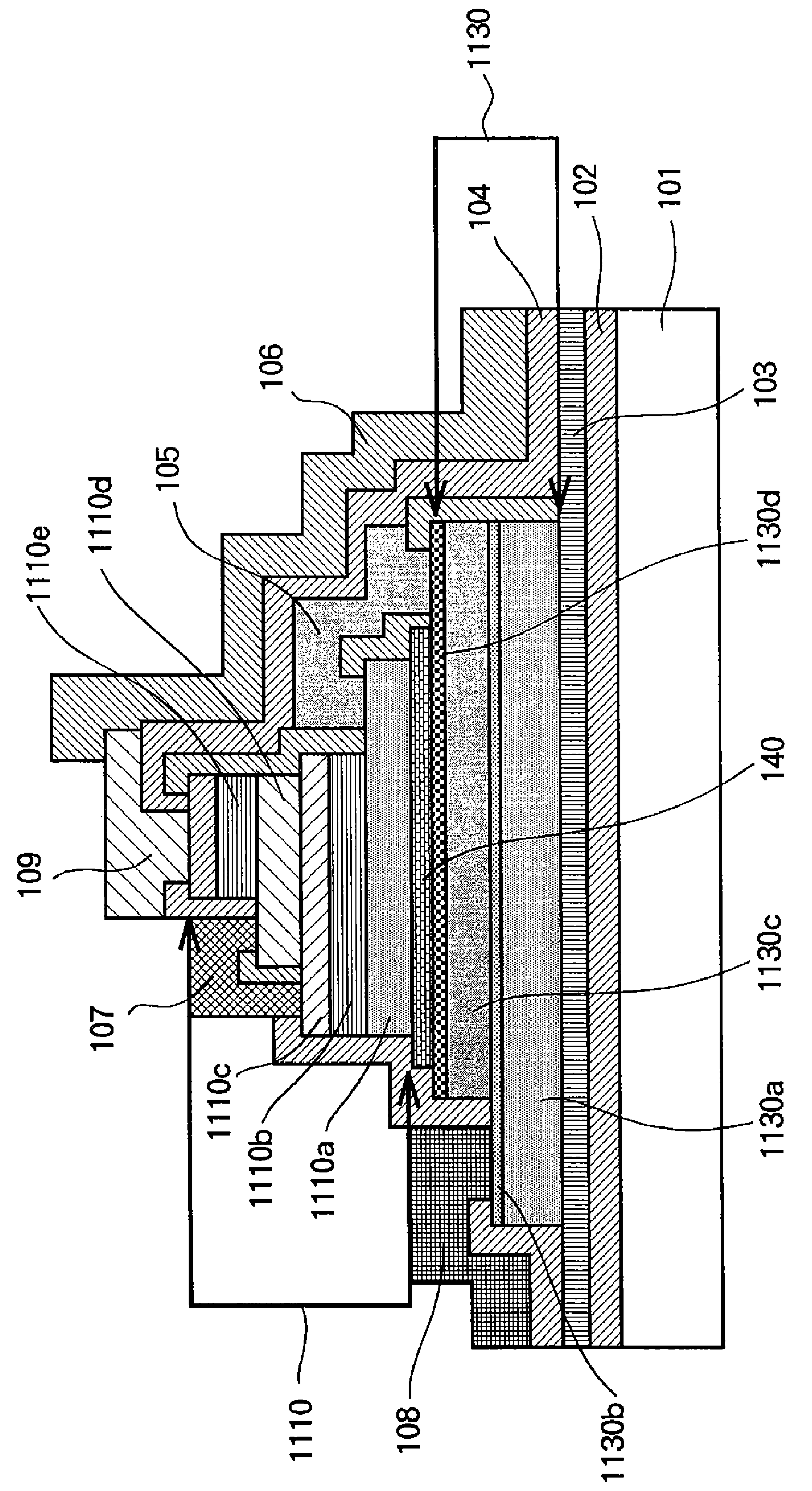
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FIG.18

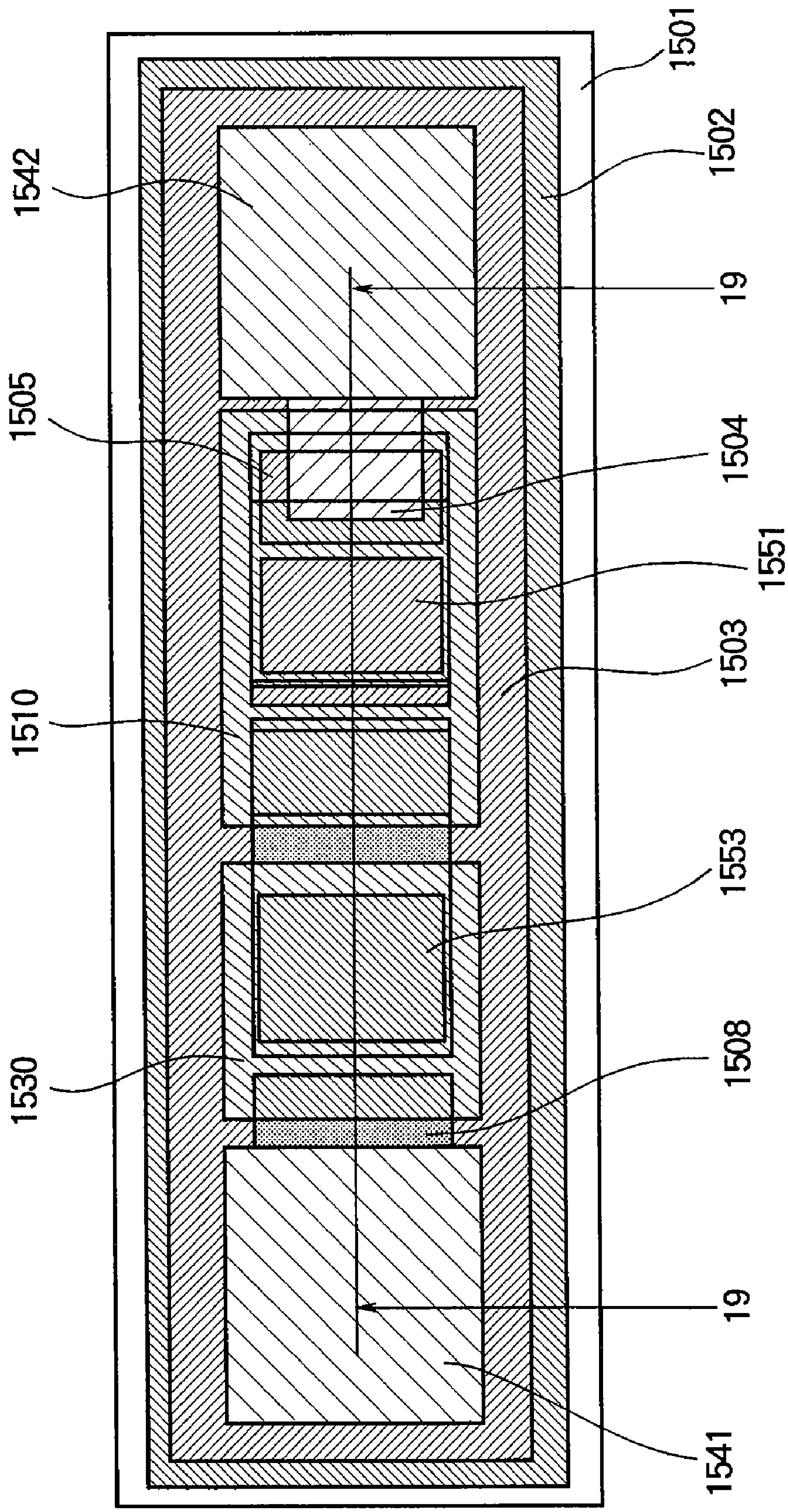
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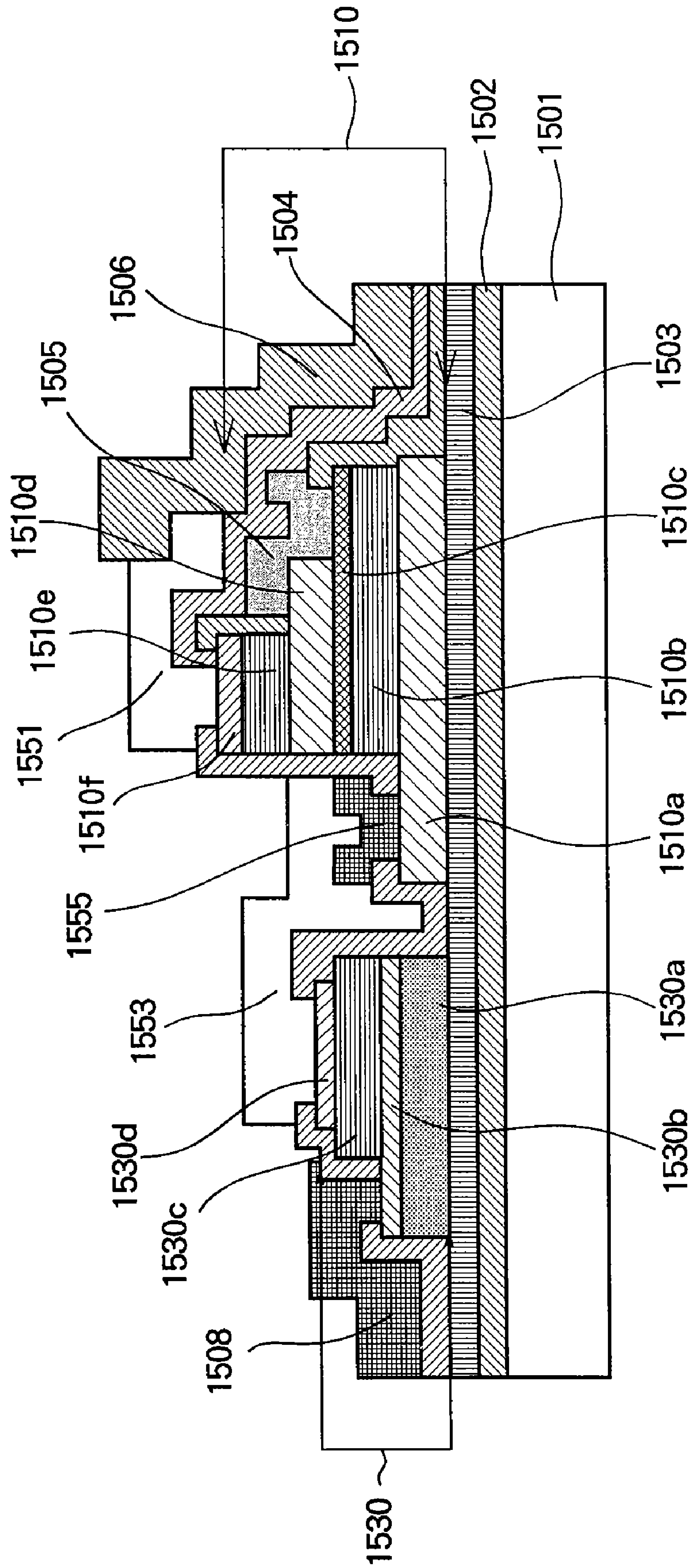
FIG.19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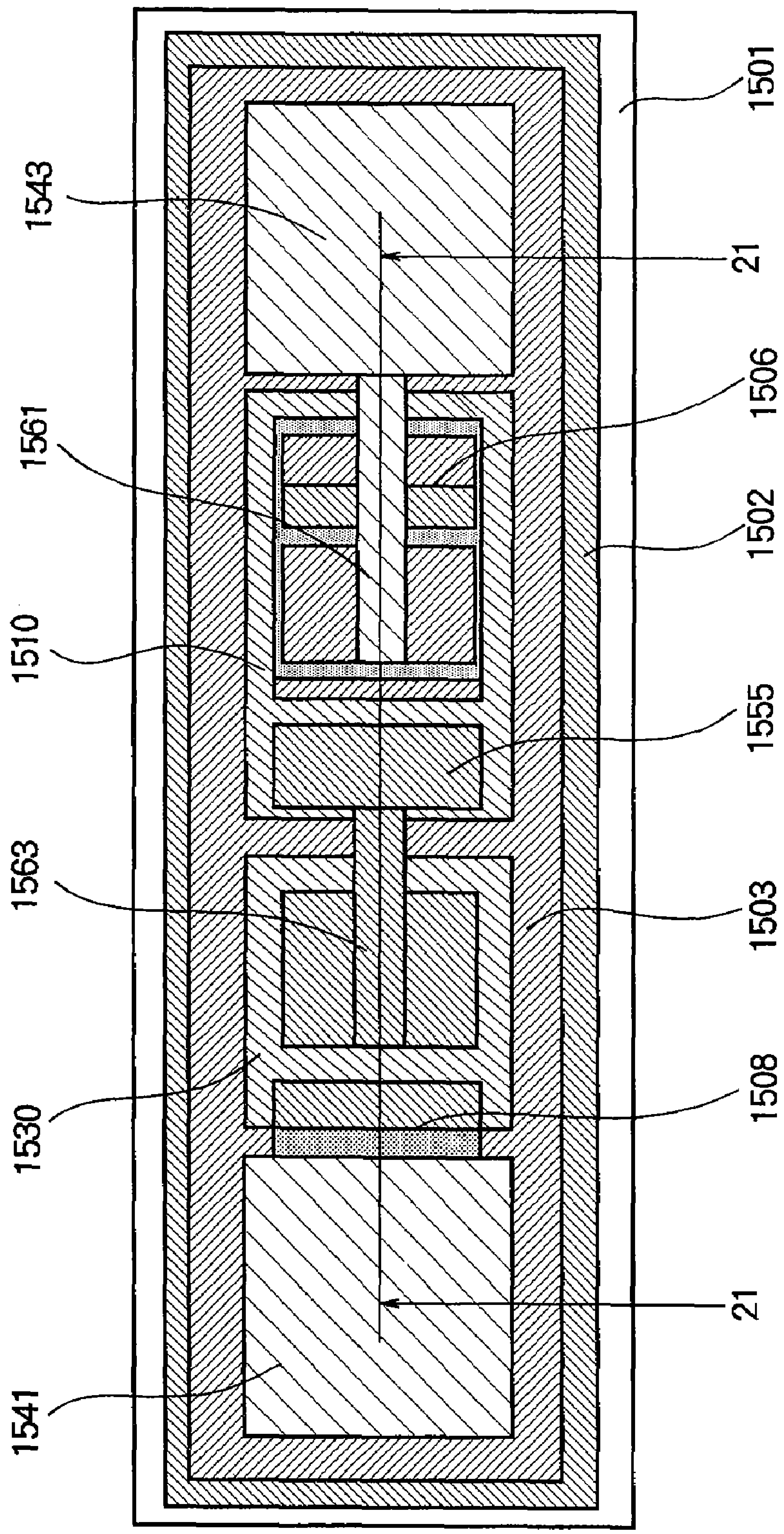
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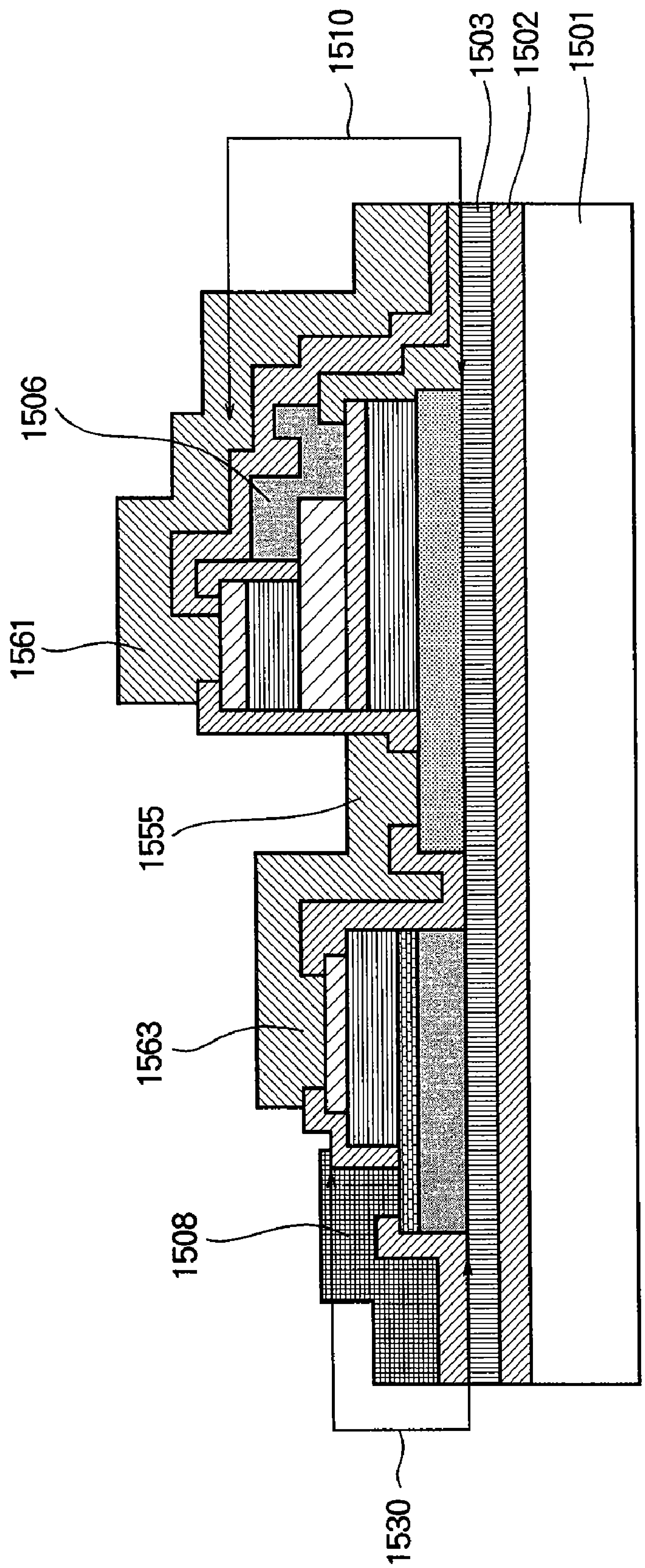
FIG.20

FIG. 21



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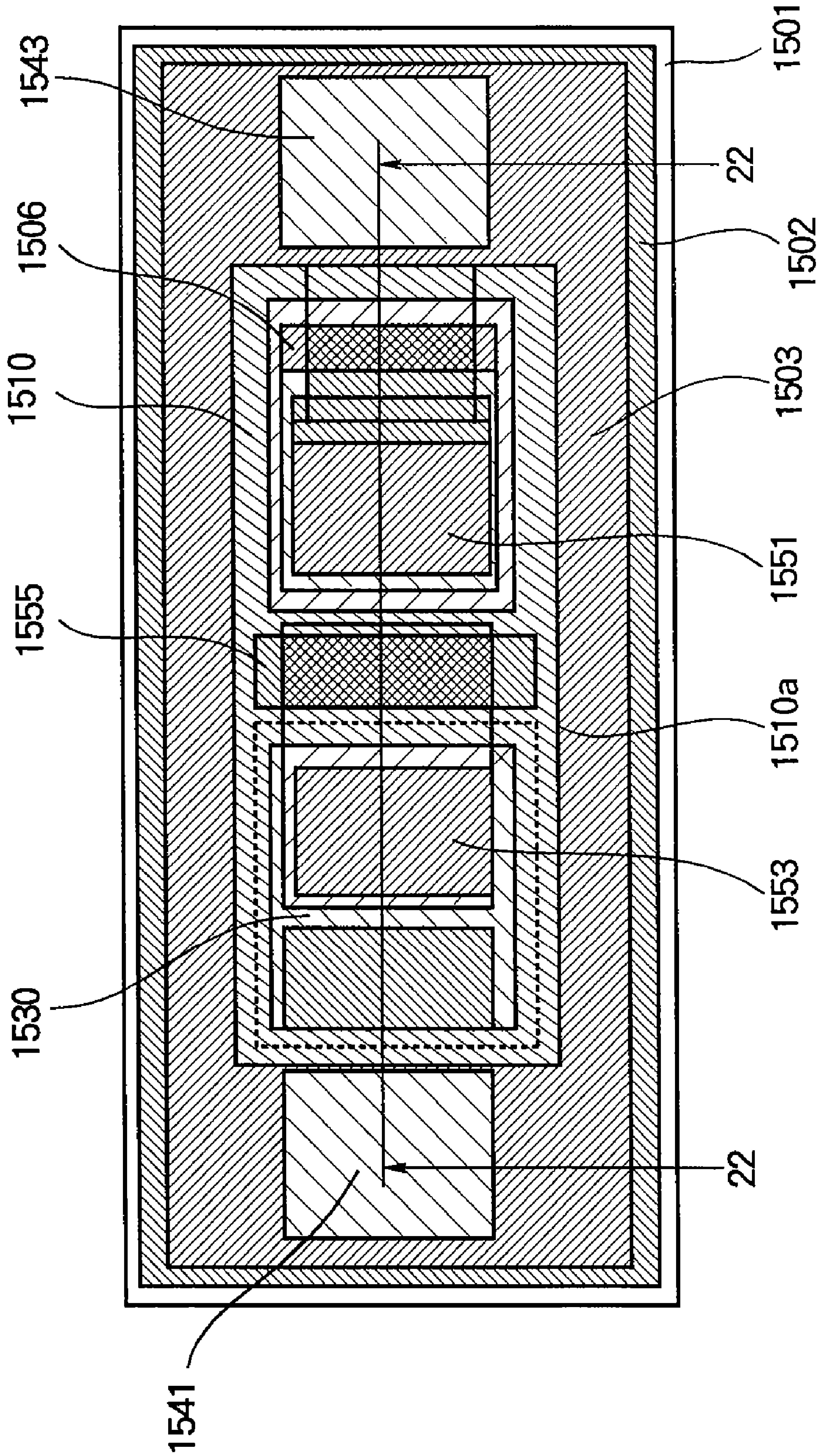
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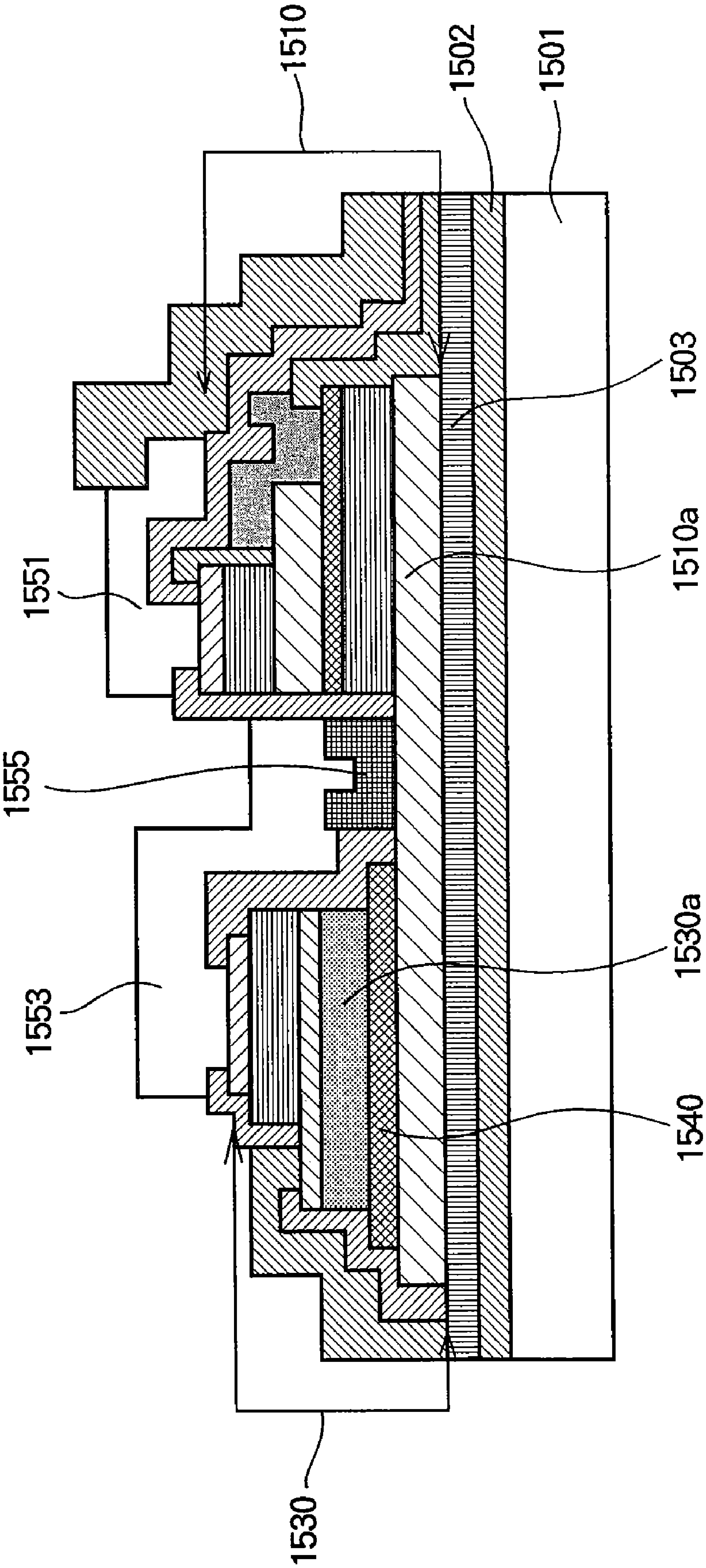
FIG. 23



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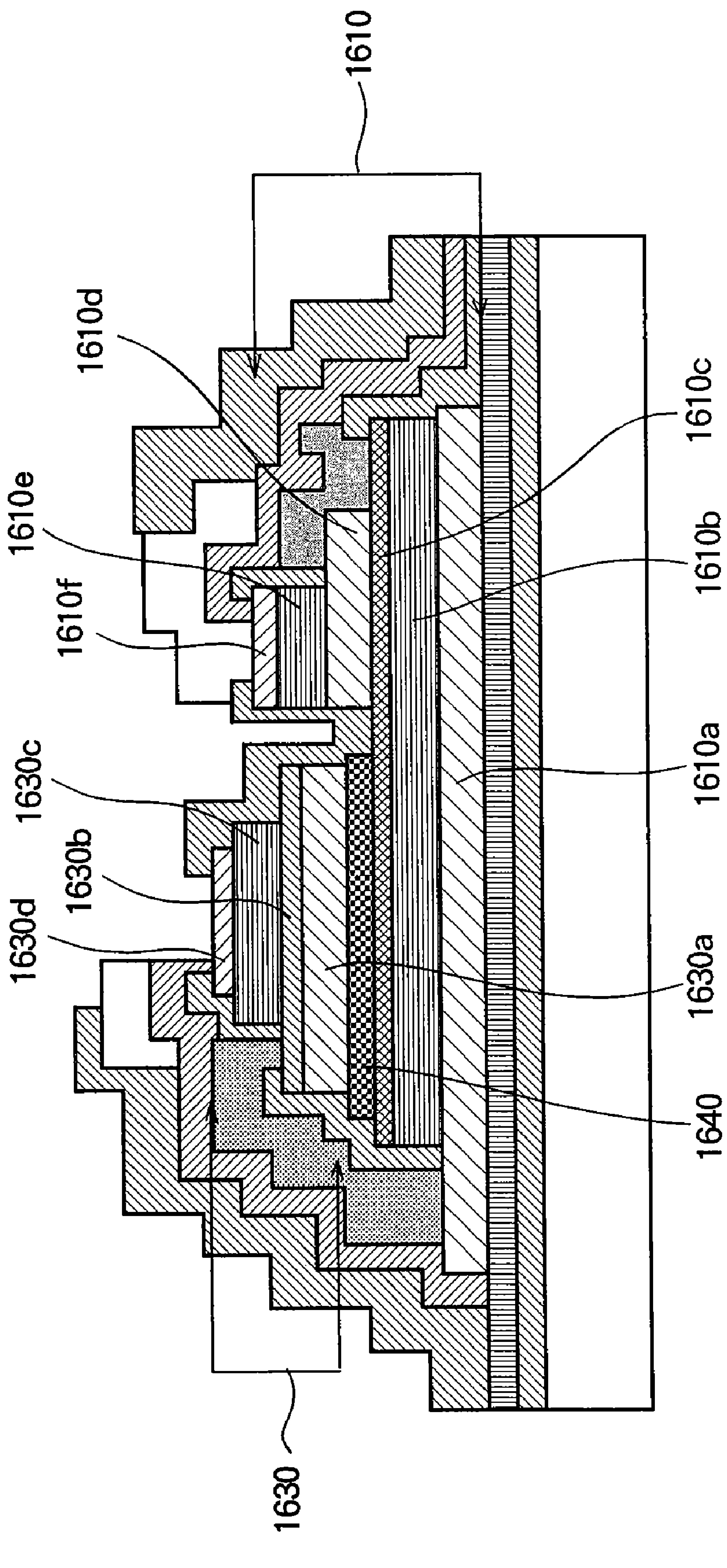
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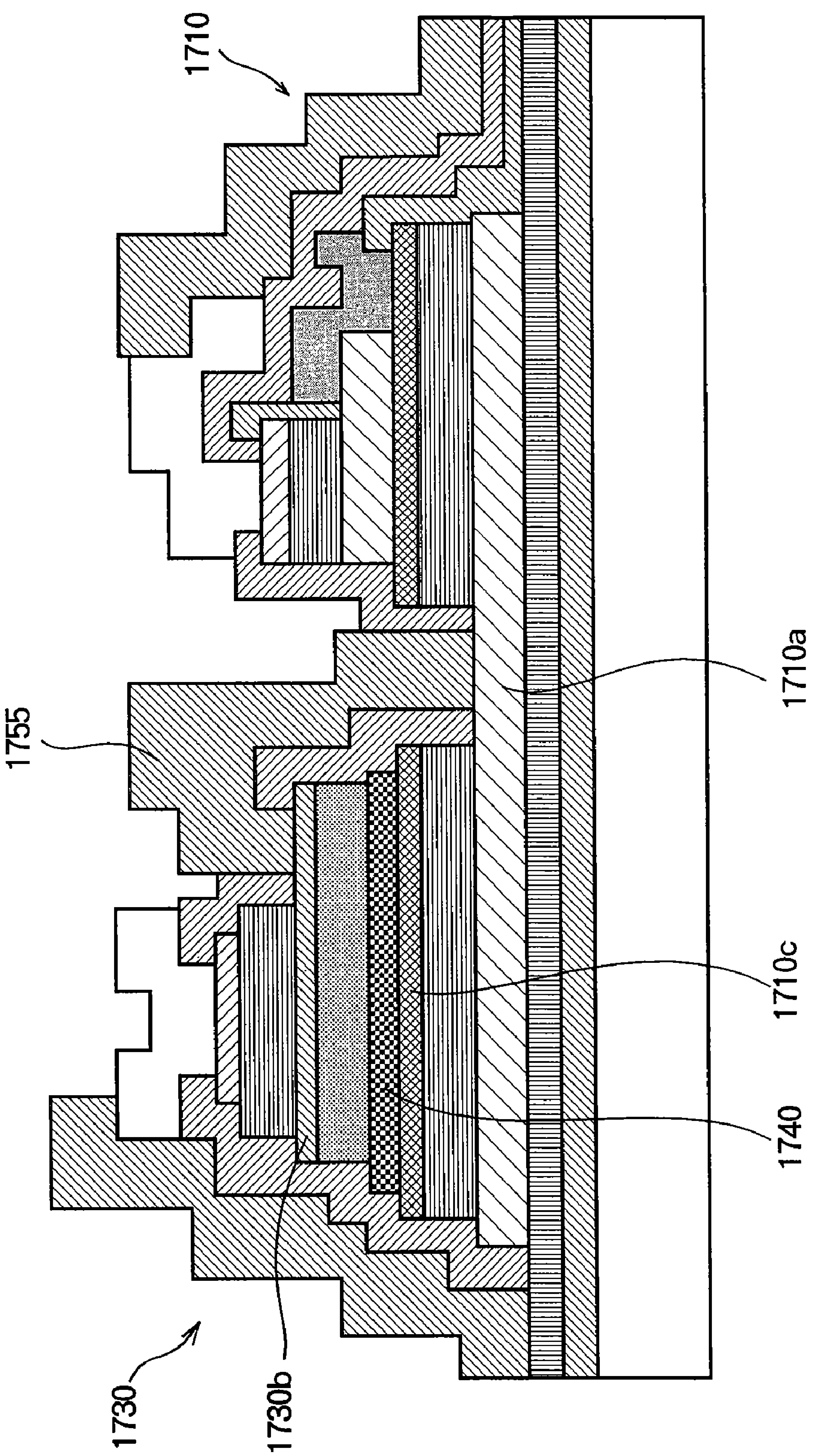

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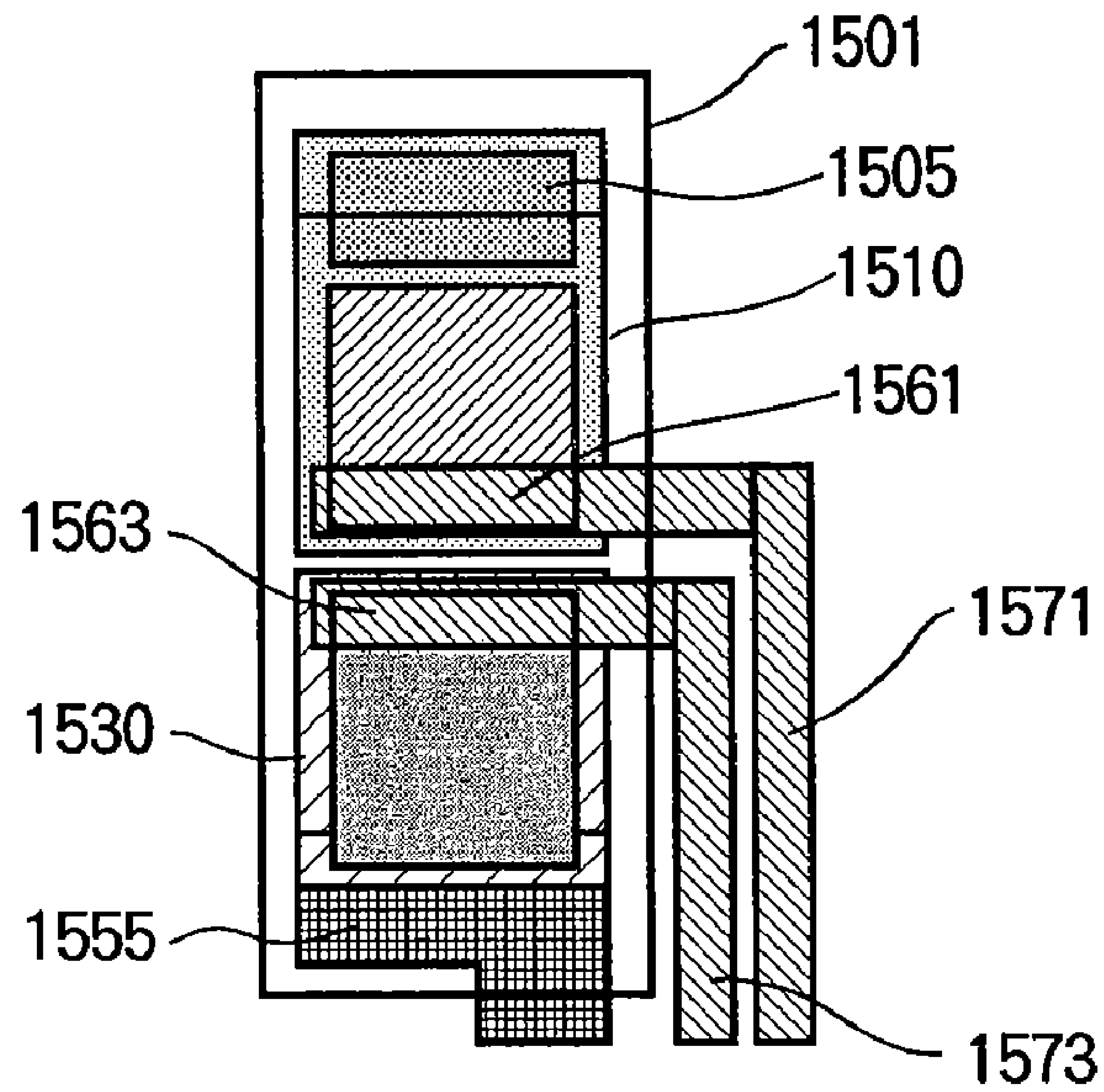
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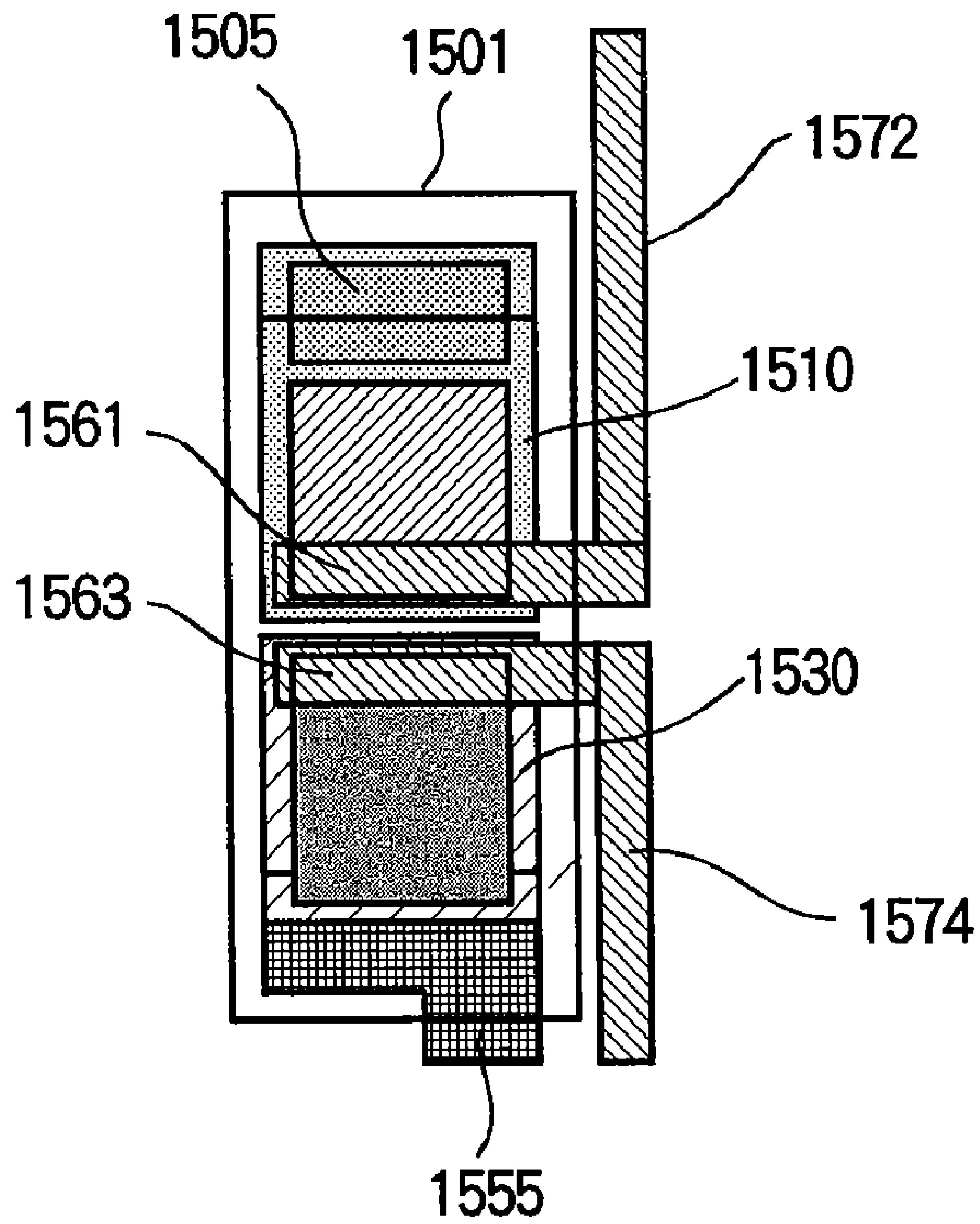
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FIG.28

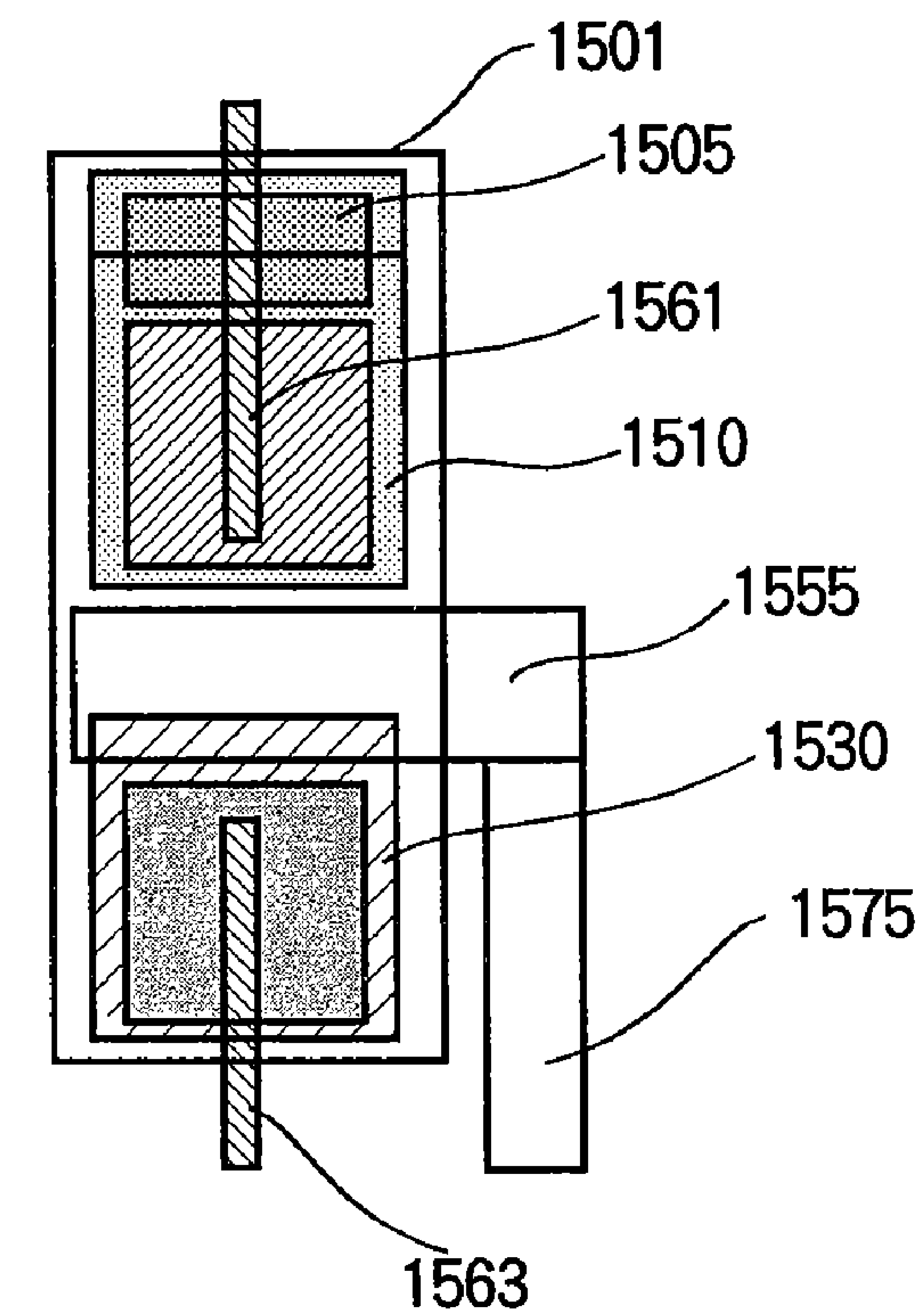
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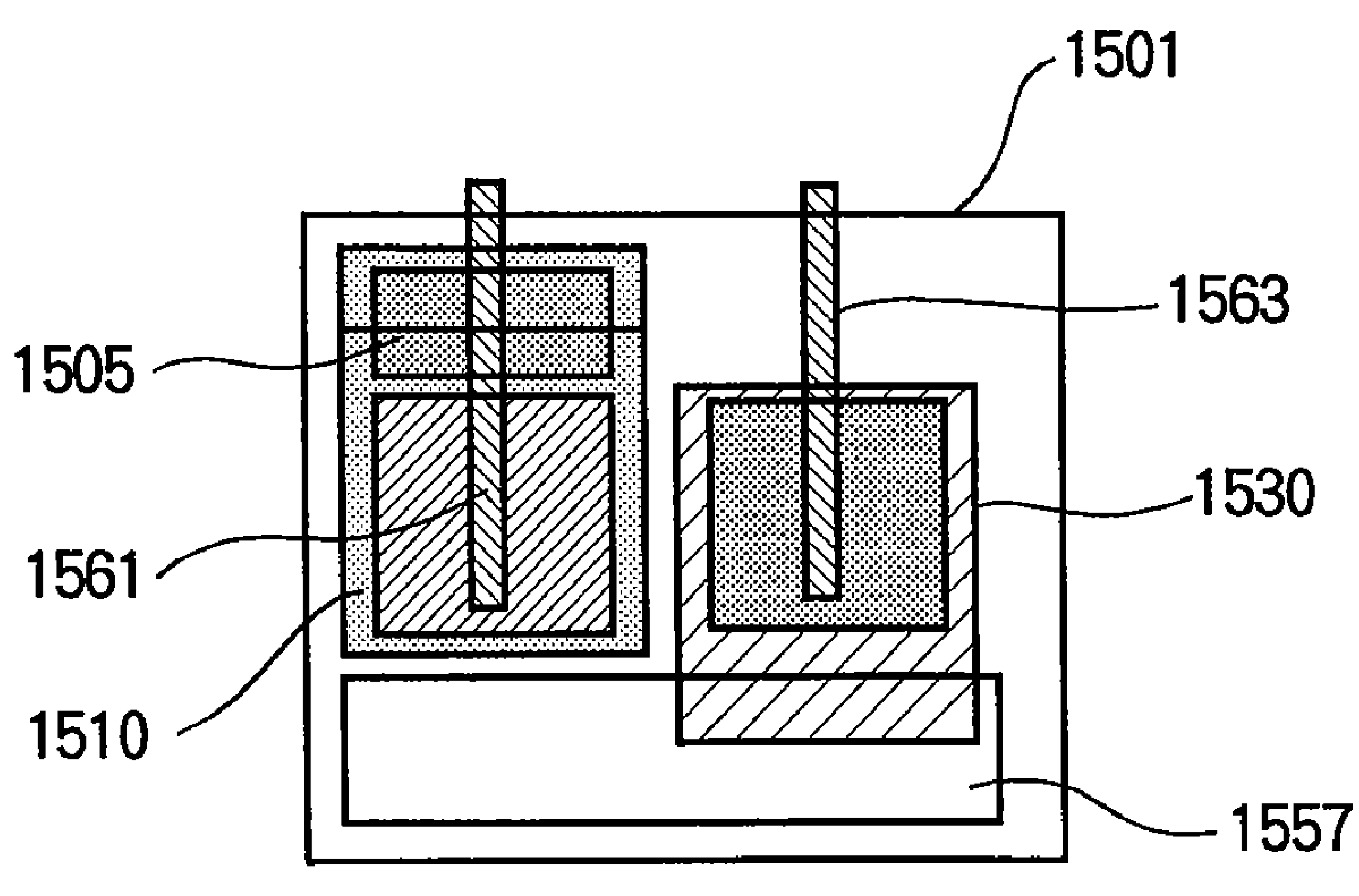
FIG.29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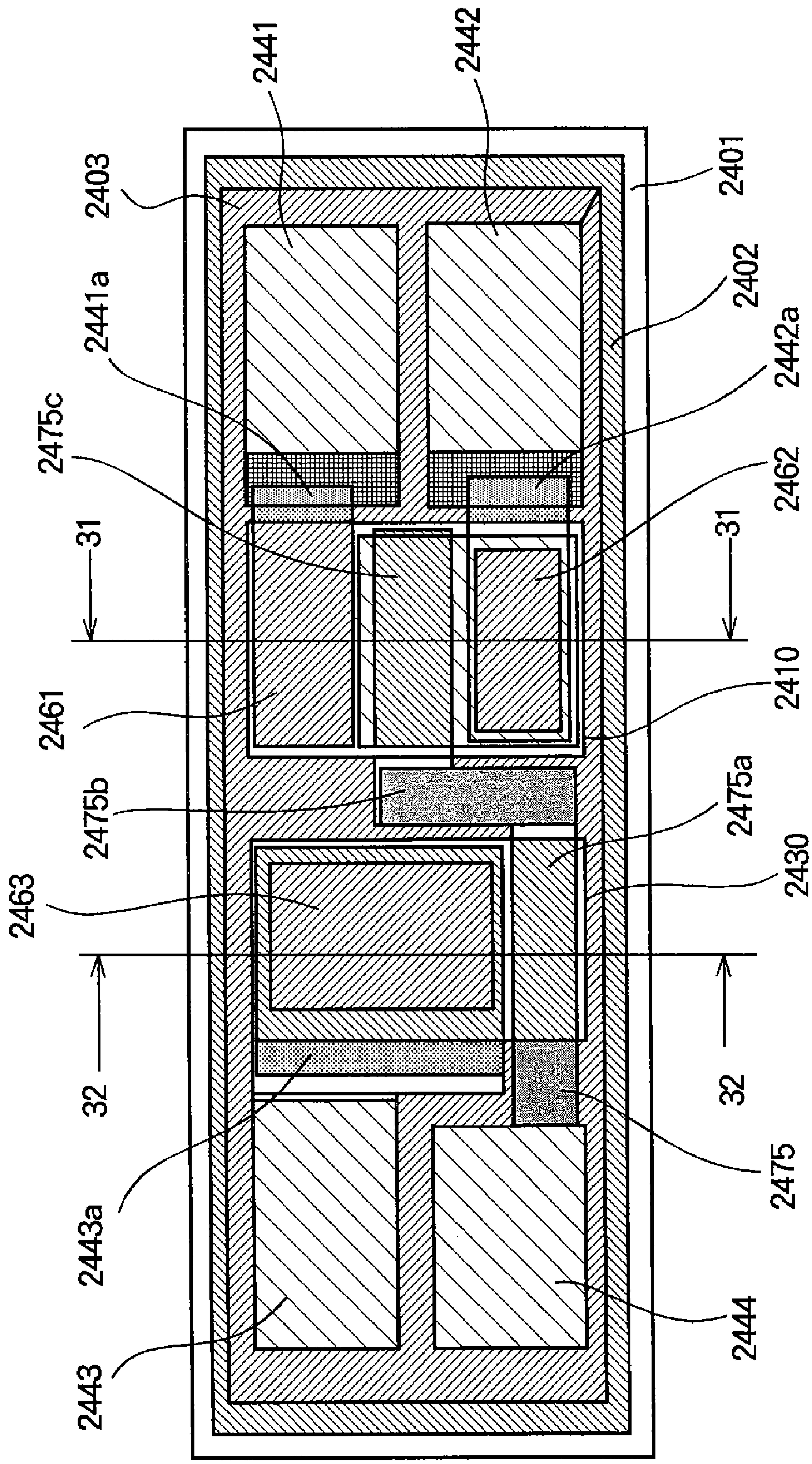
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FIG.31

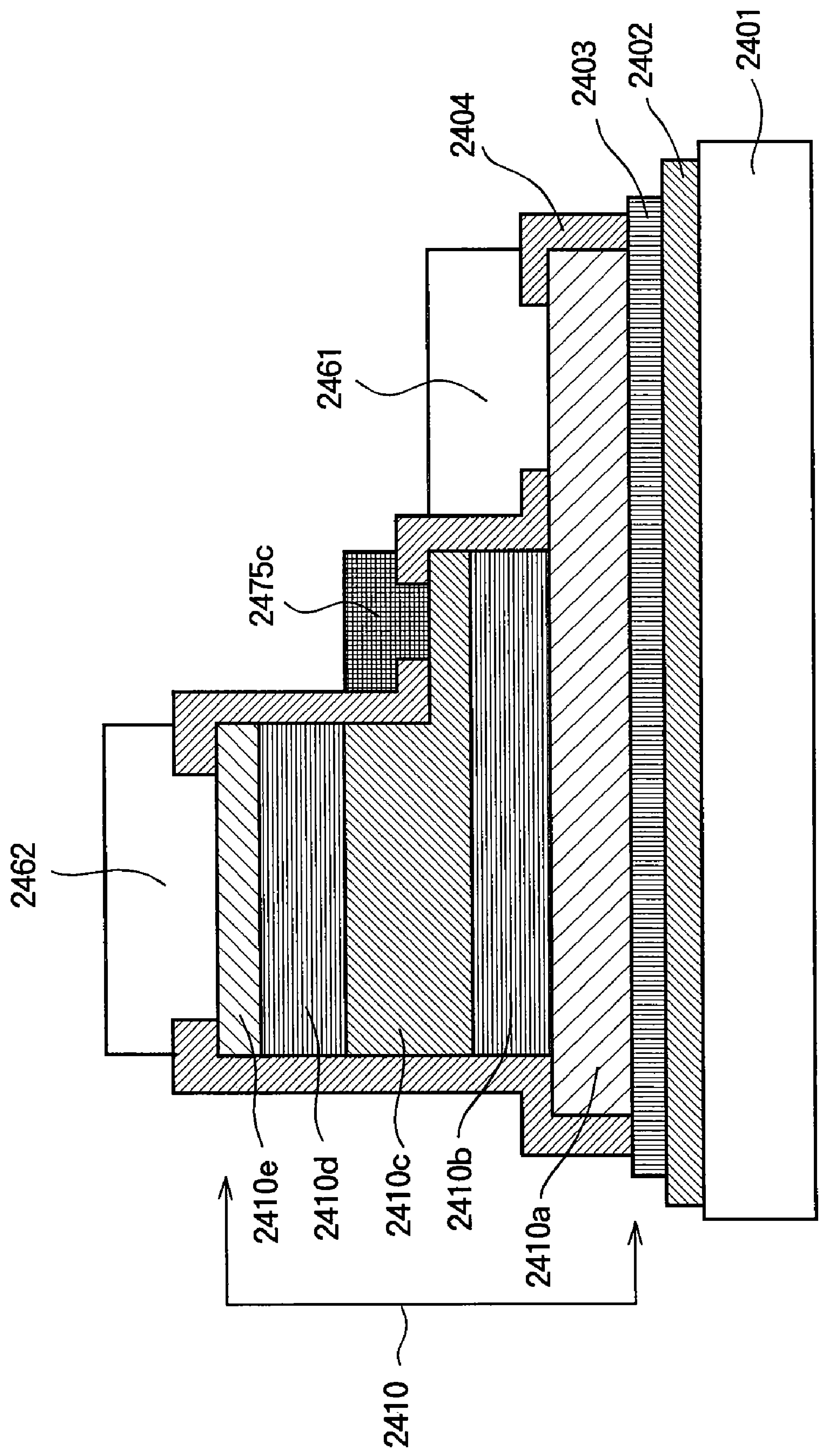
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FIG.32

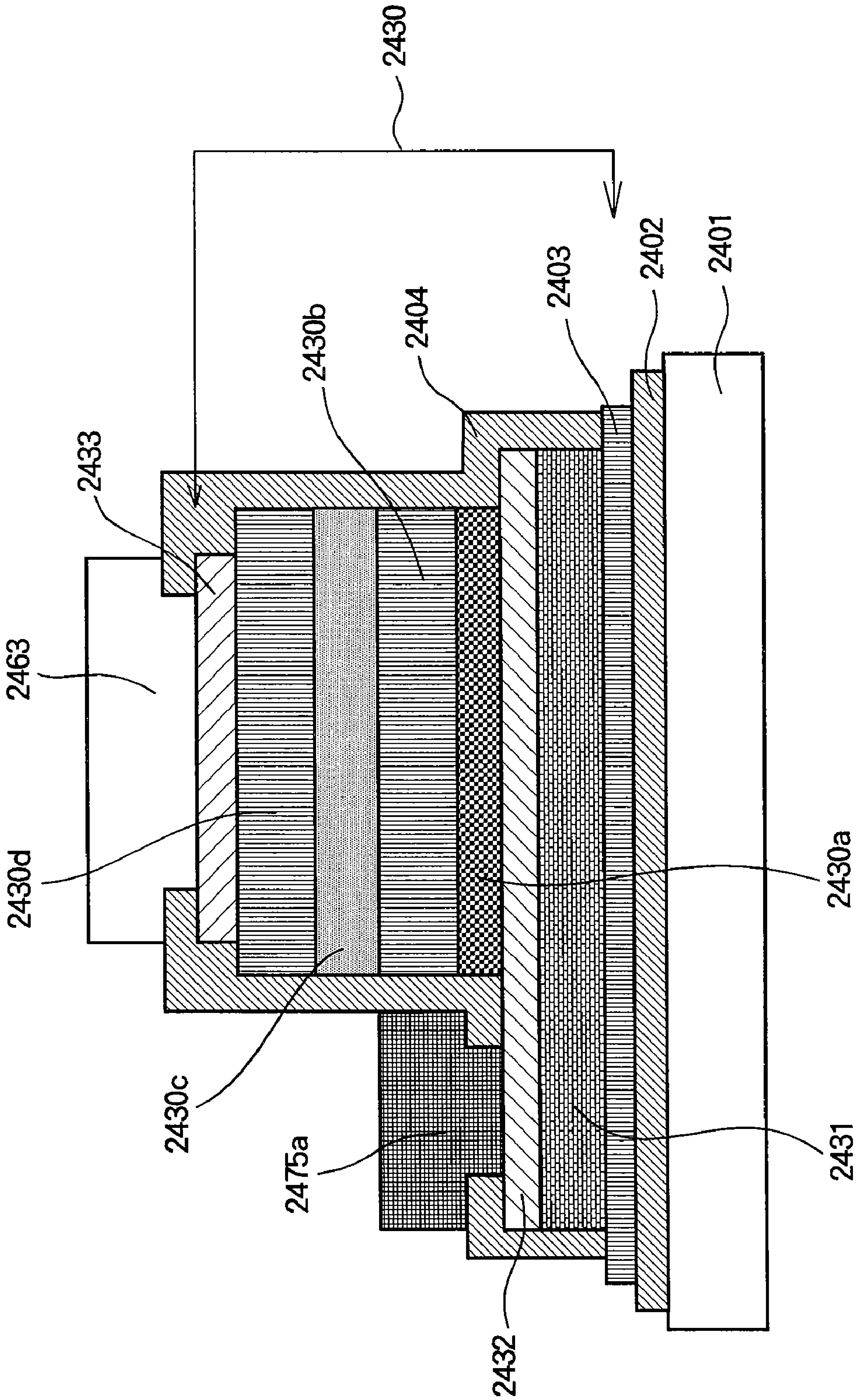
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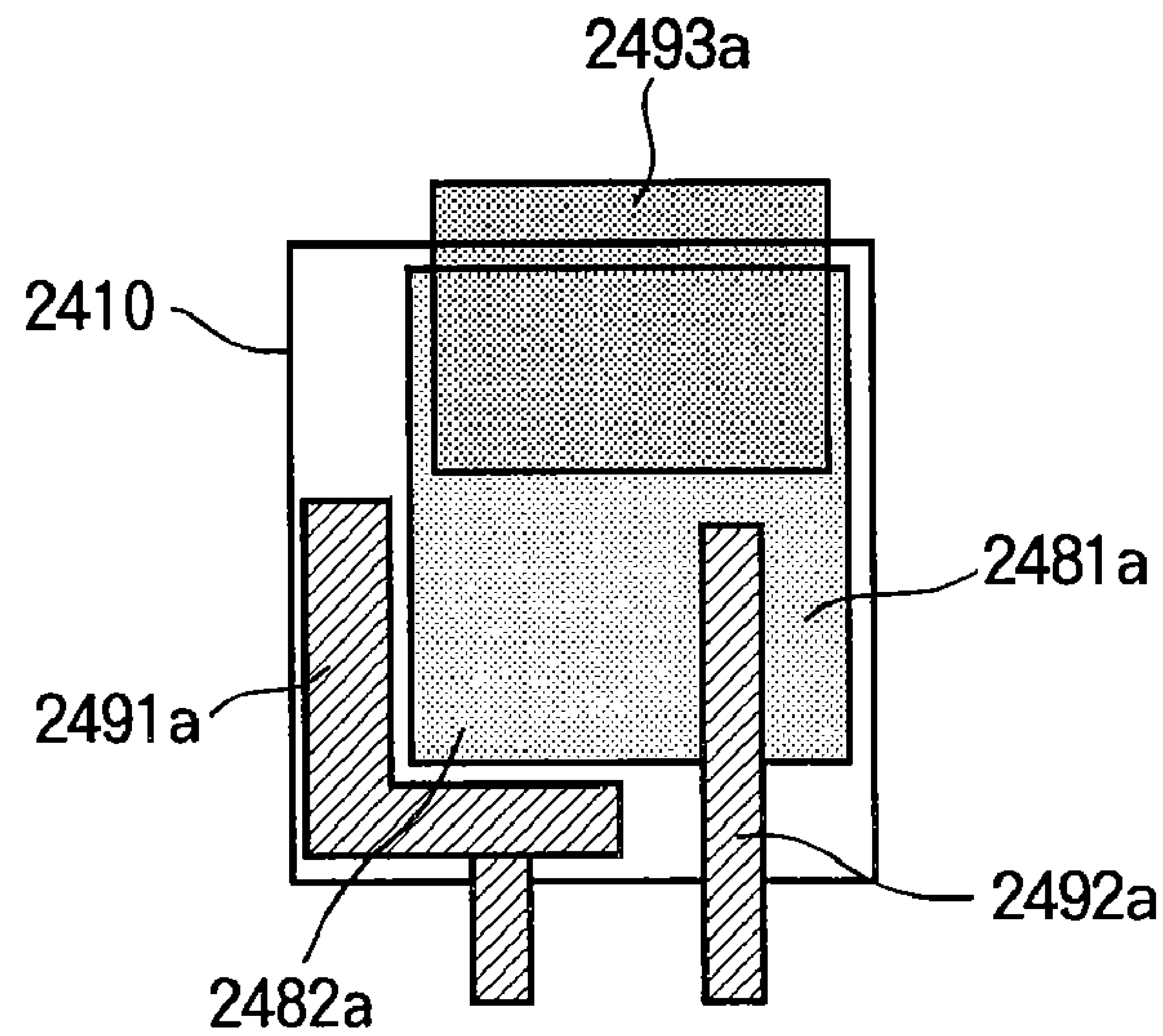
FIG. 33



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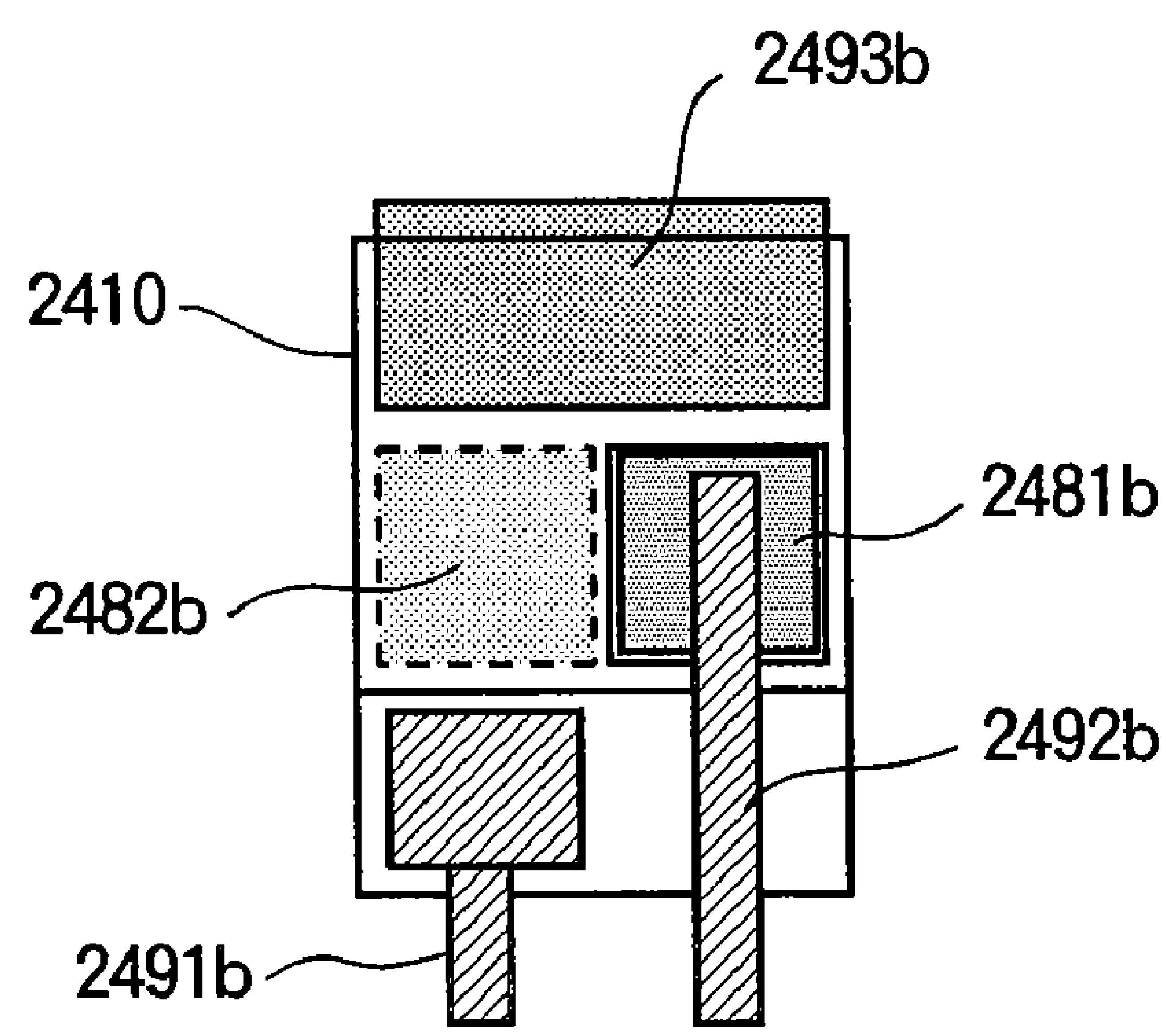

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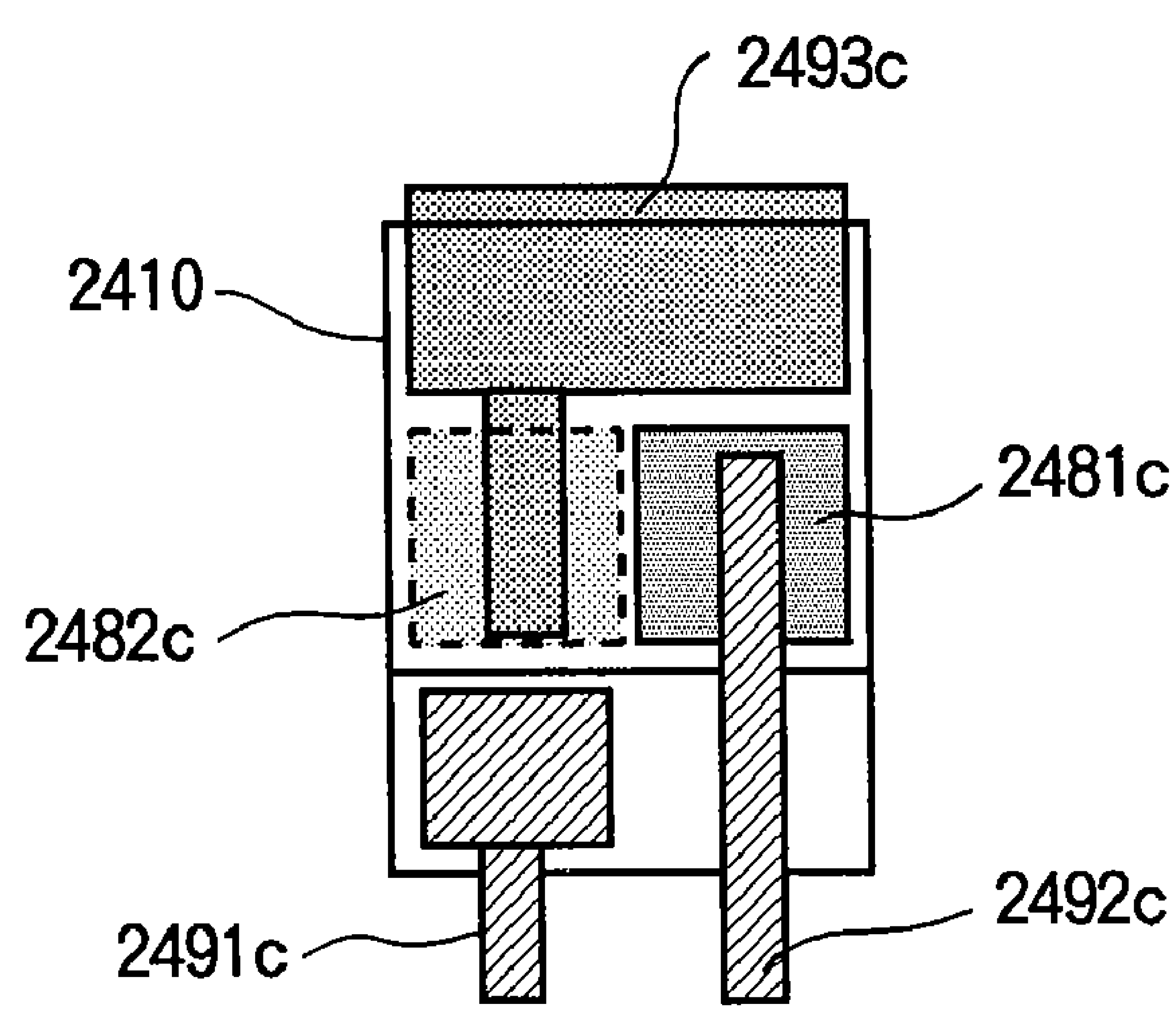
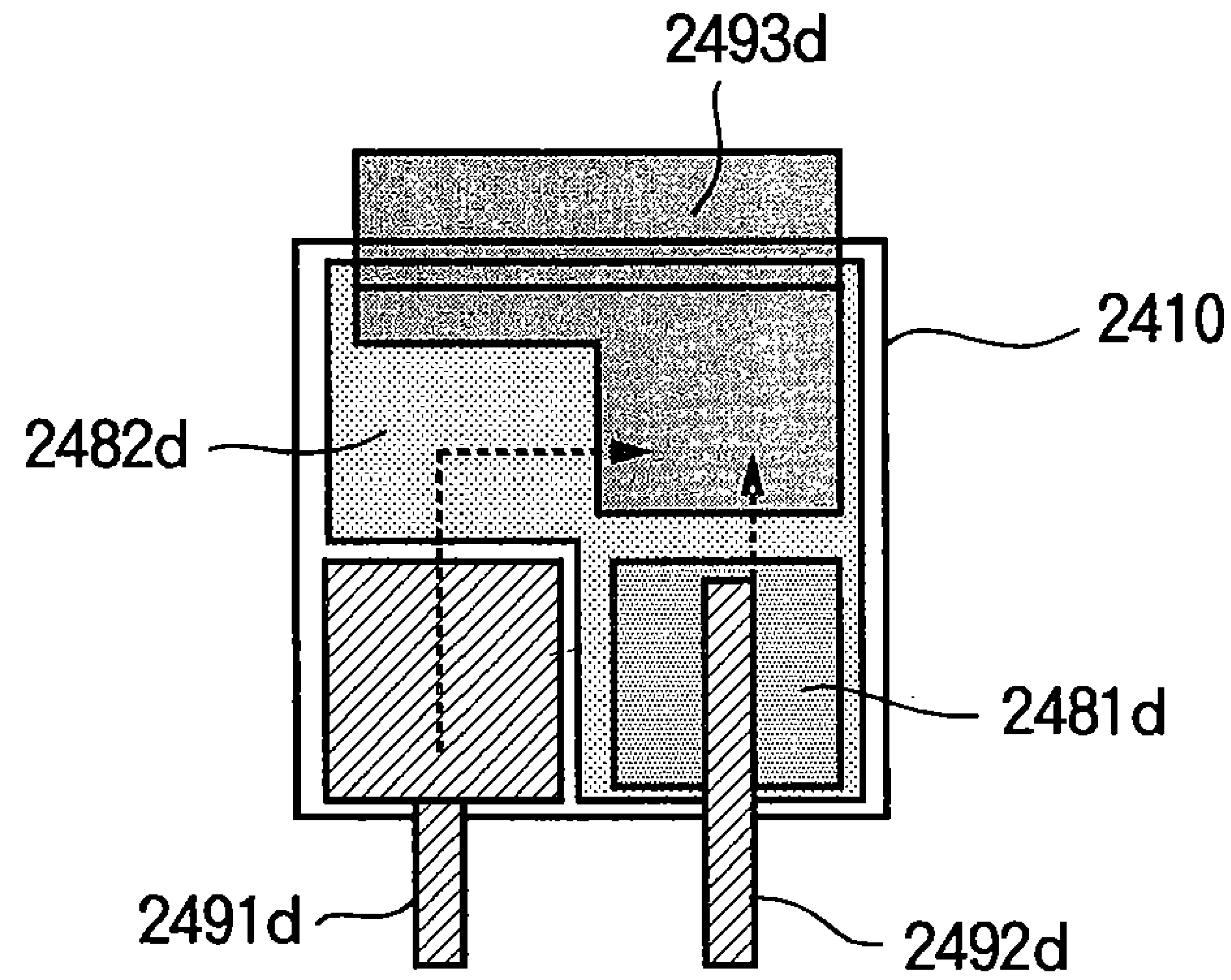


FIG.36



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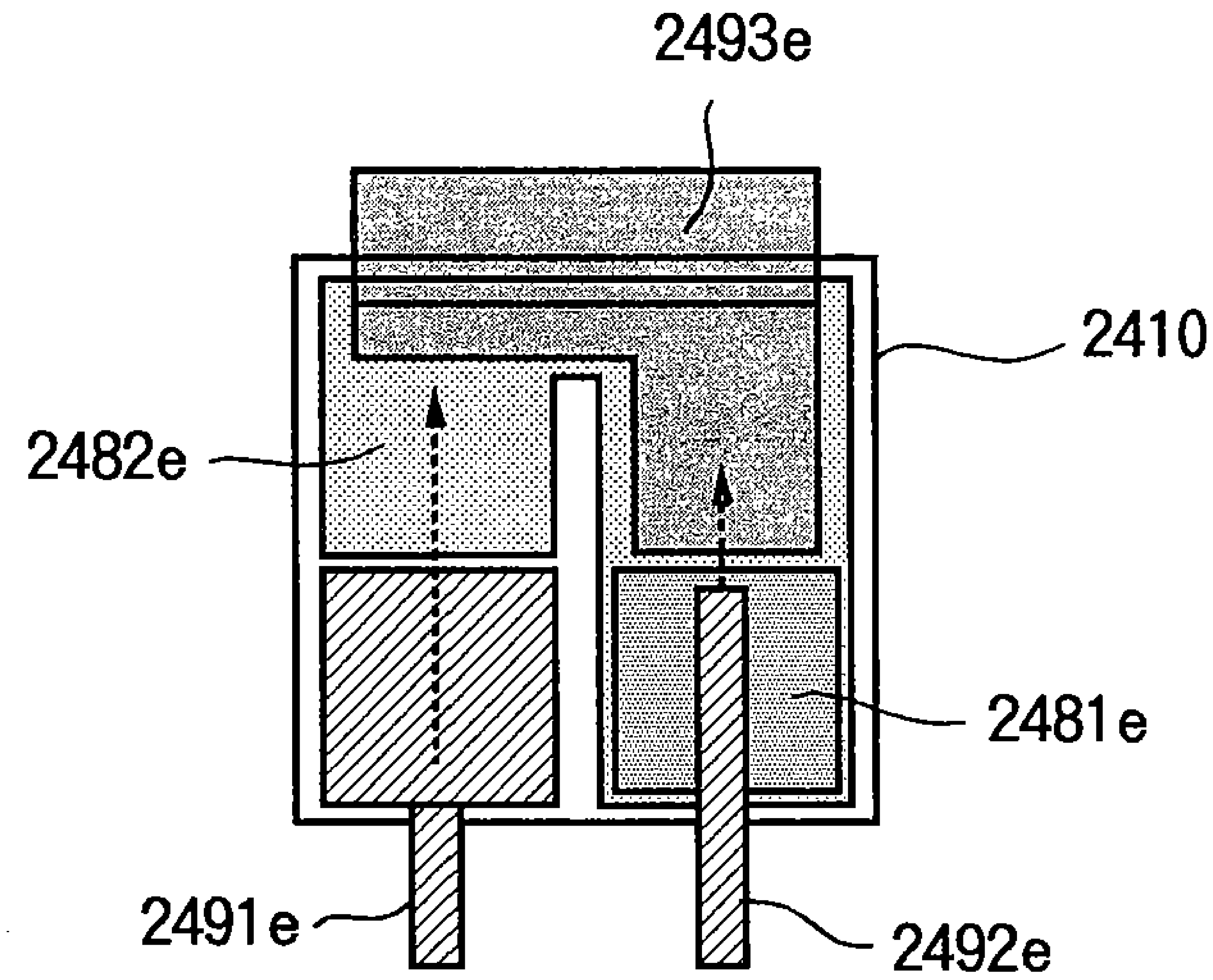

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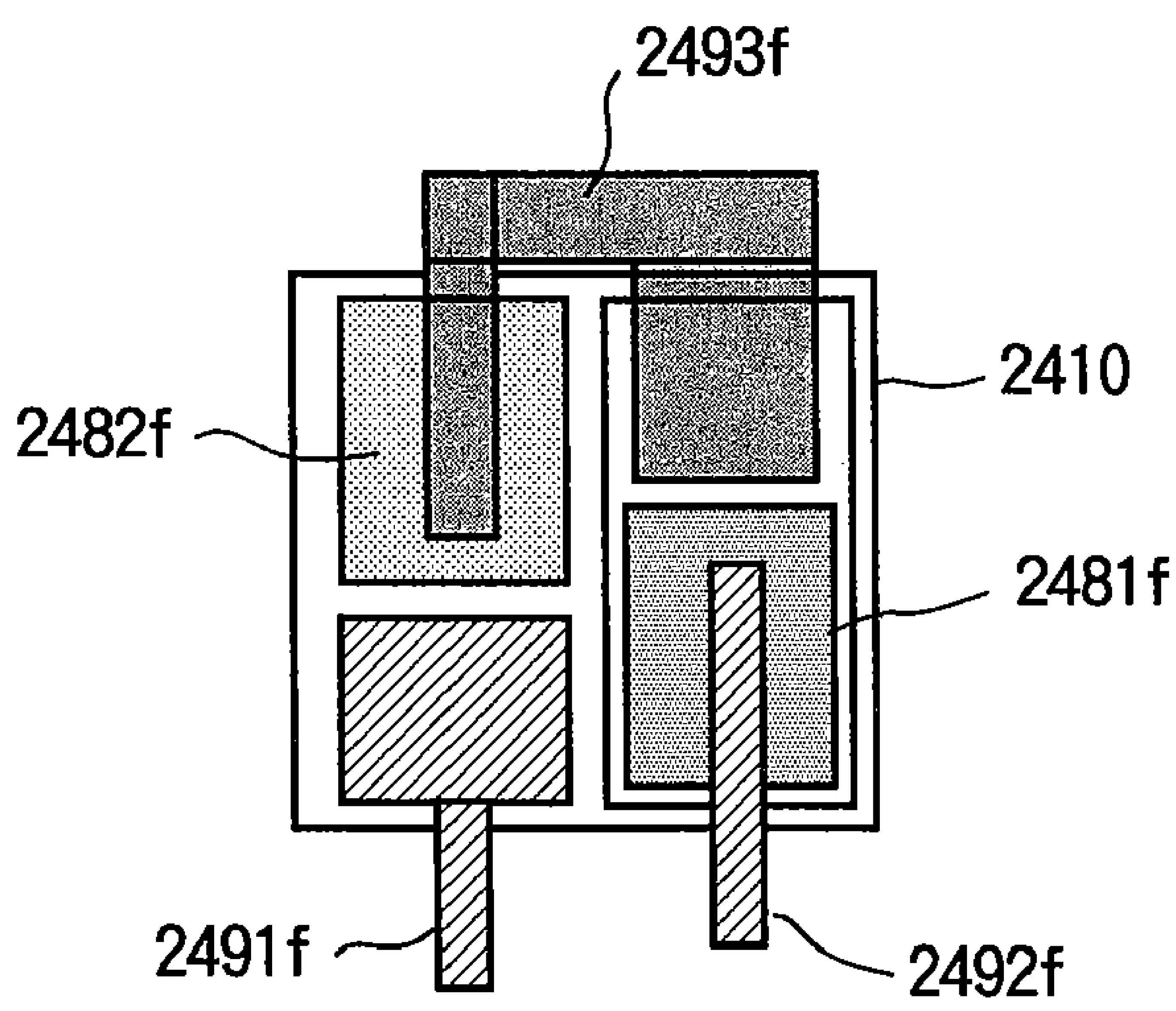

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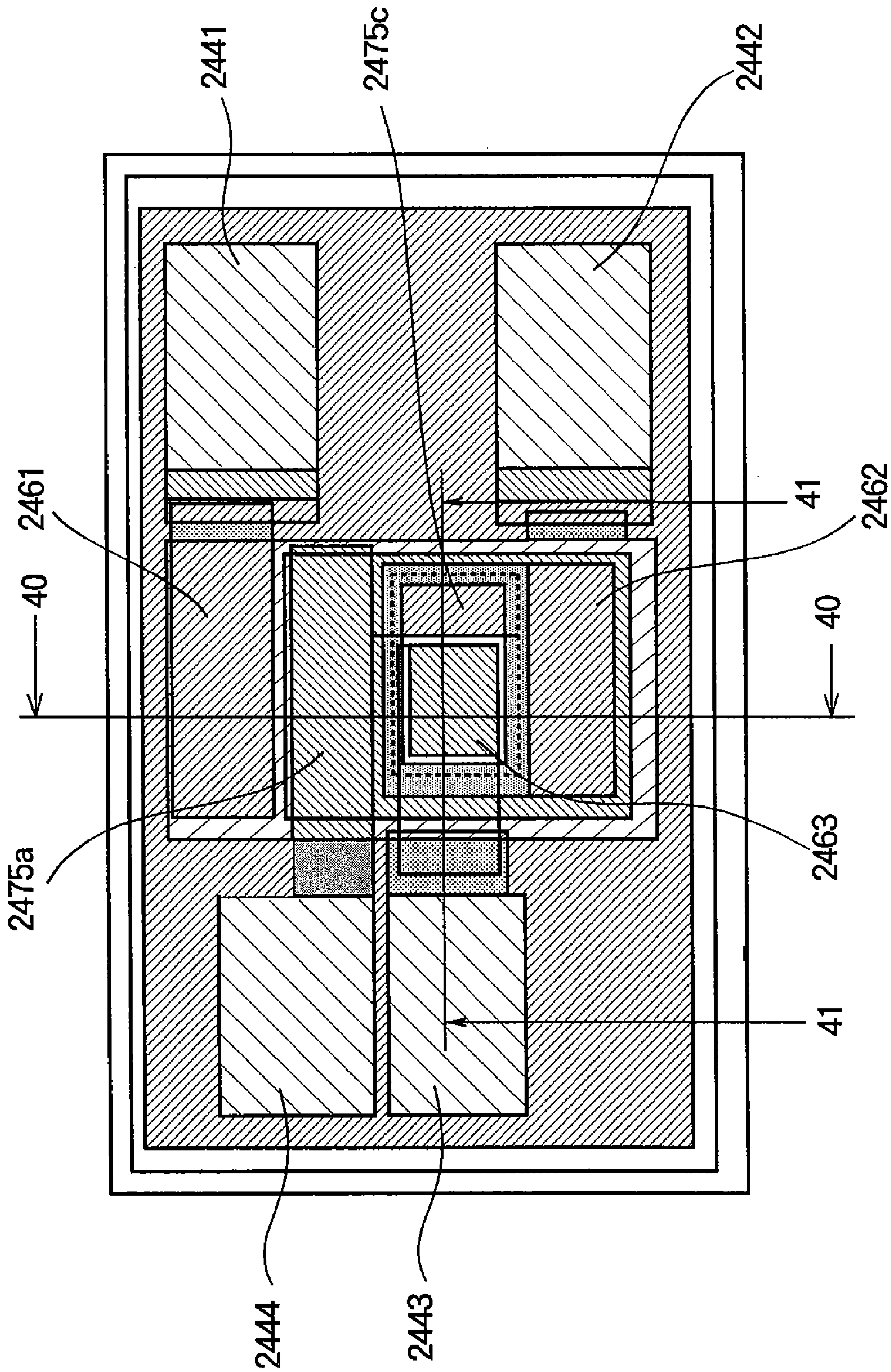
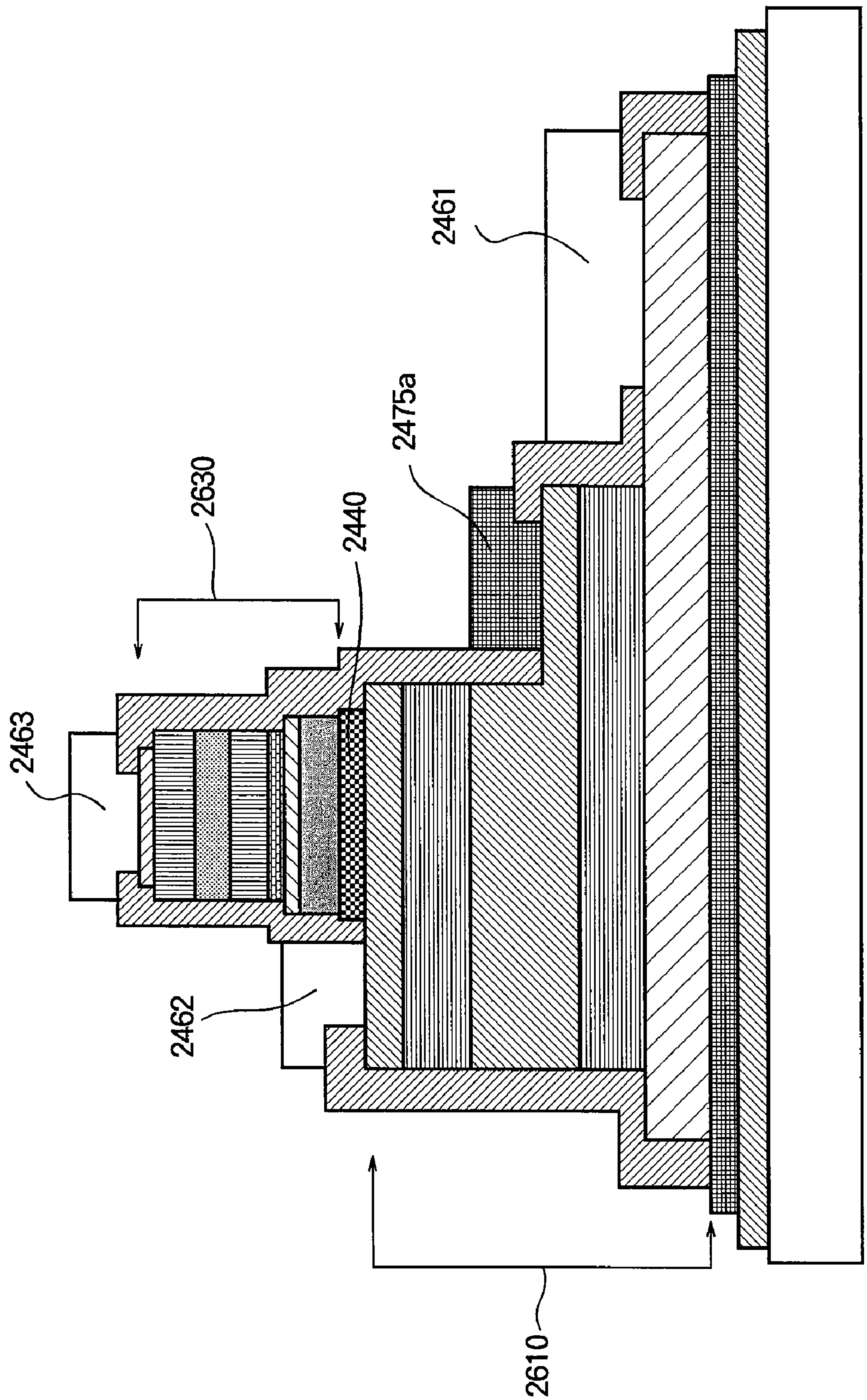


FIG. 40



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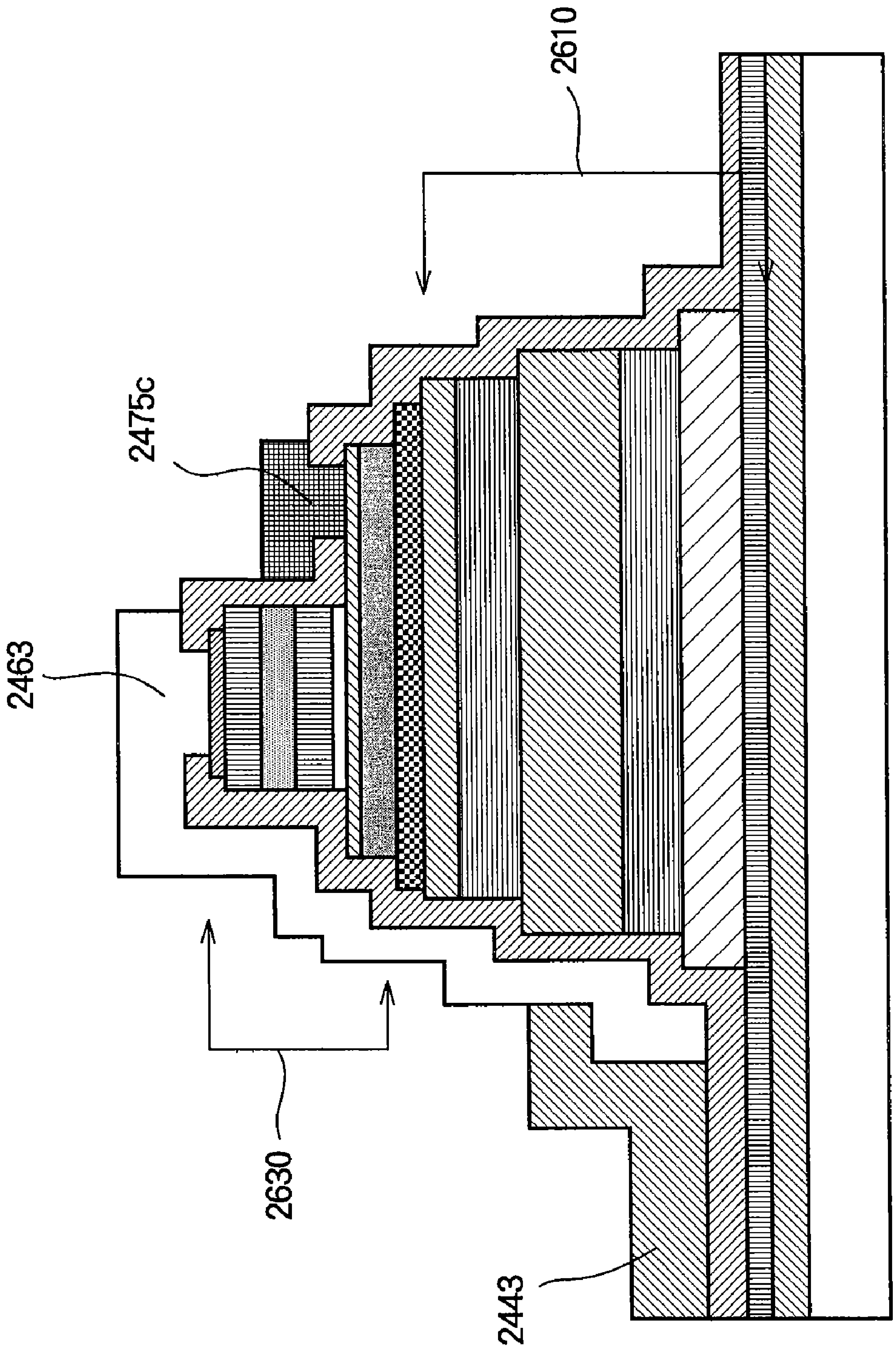

FIG.42

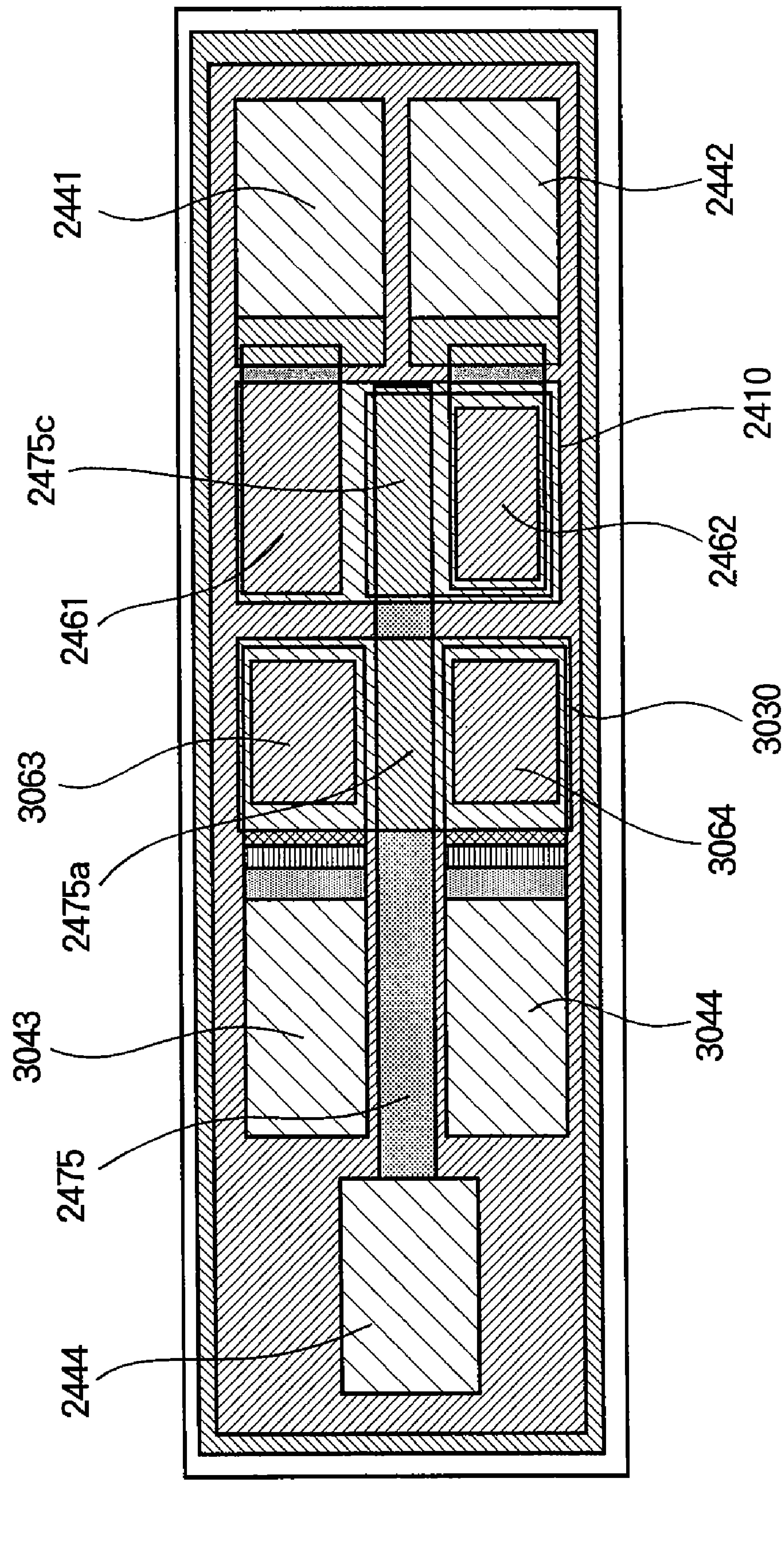
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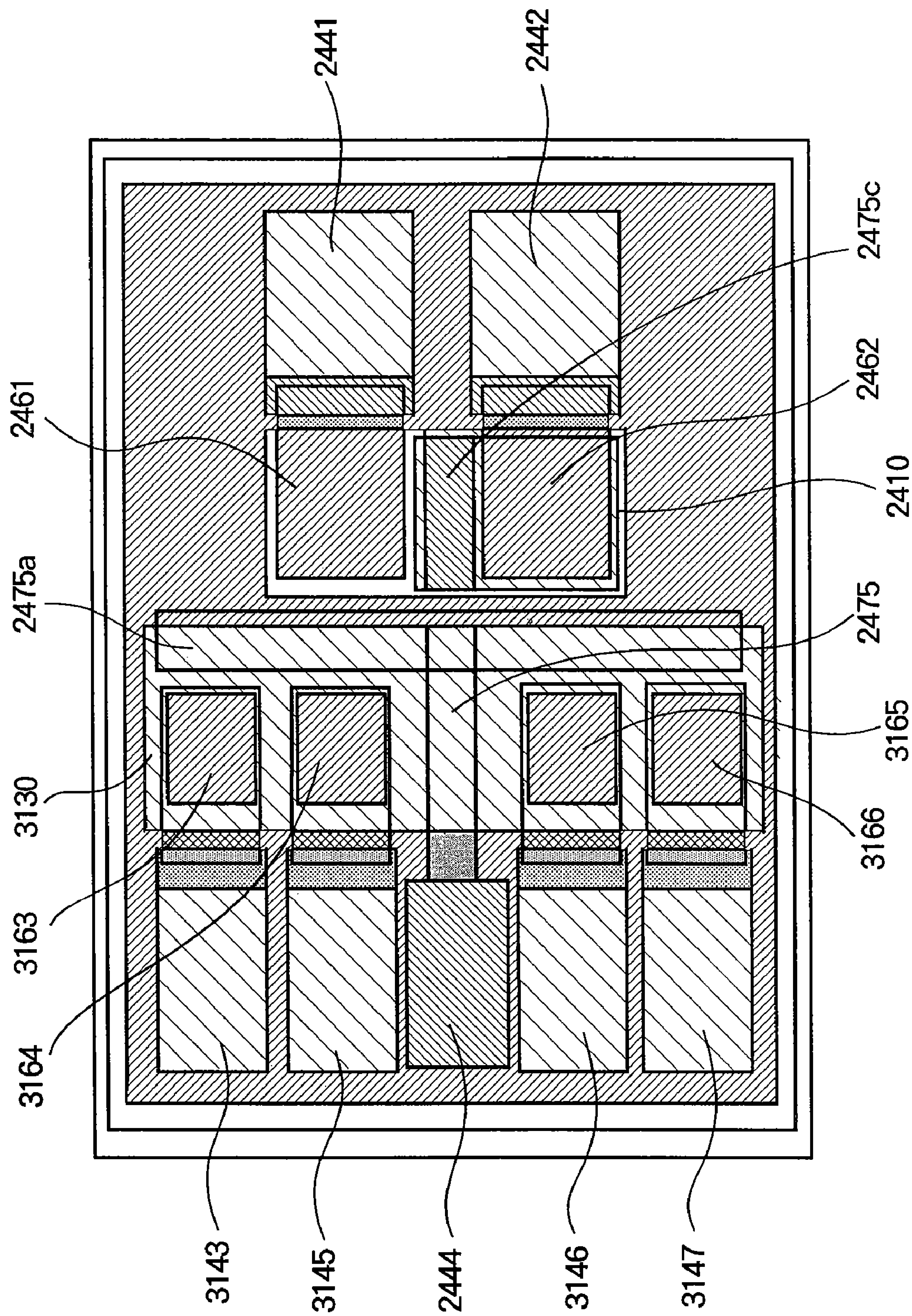
FIG. 43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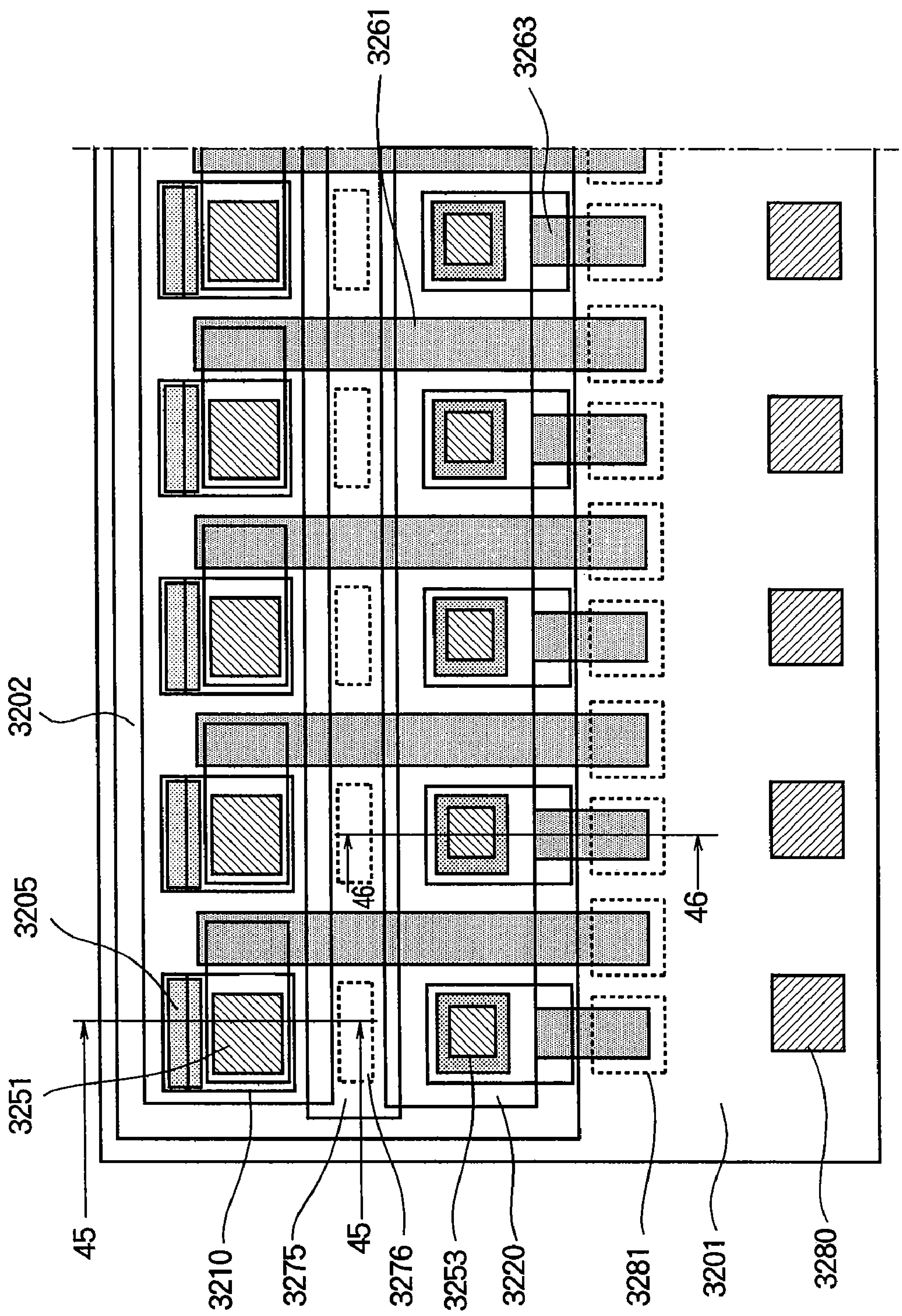
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FIG. 44

FIG. 45

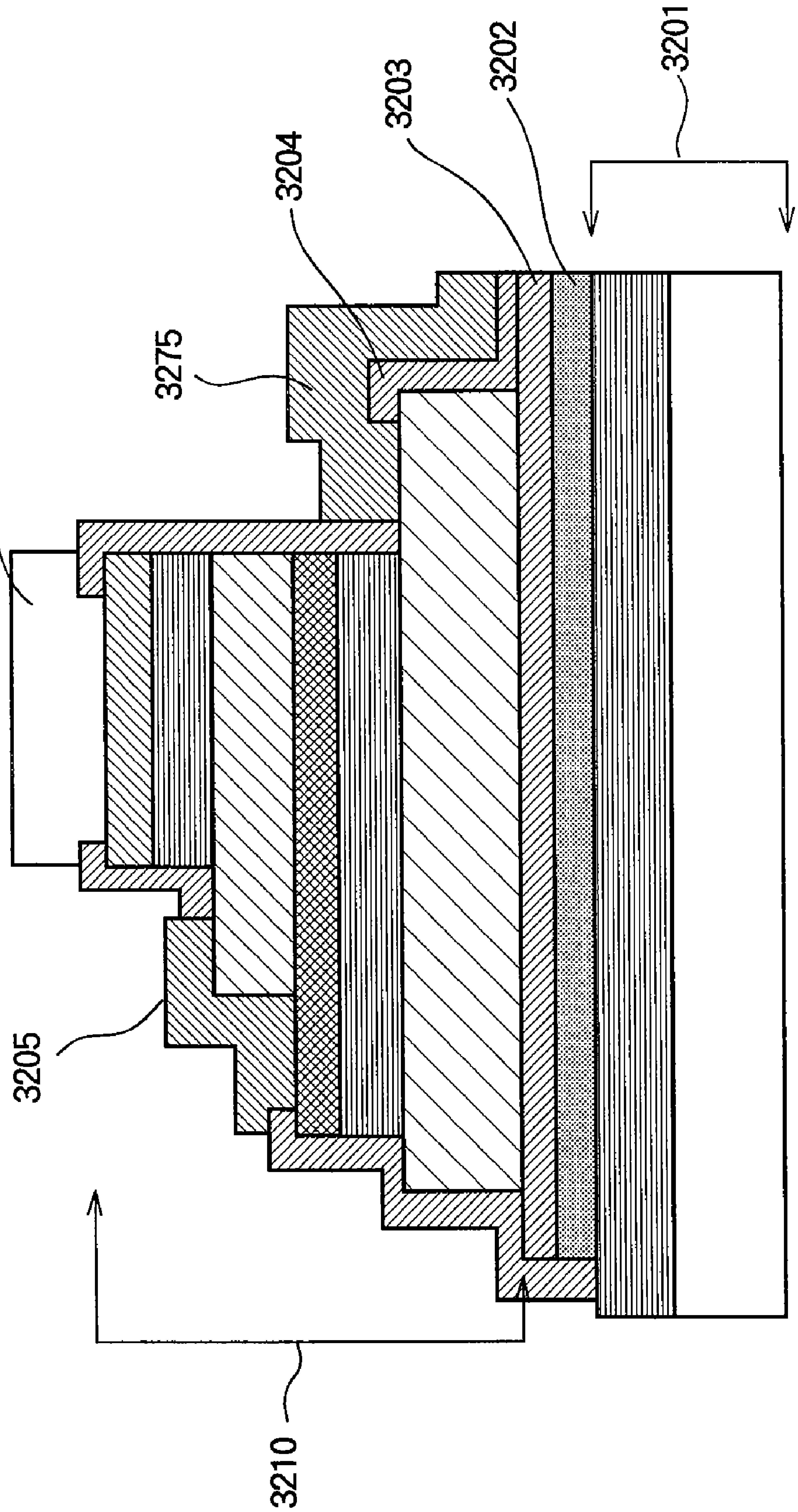

FIG.46

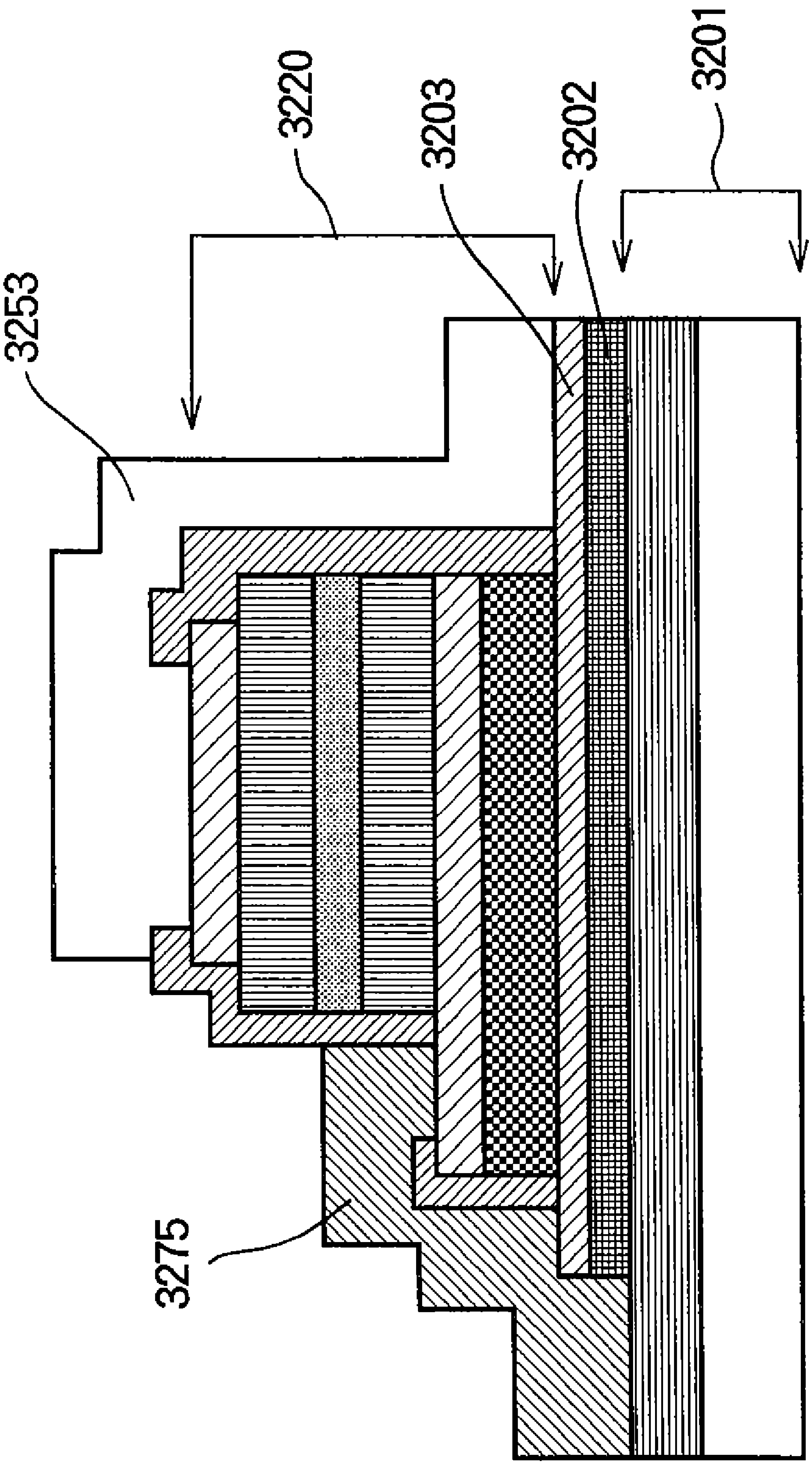

FIG. 47

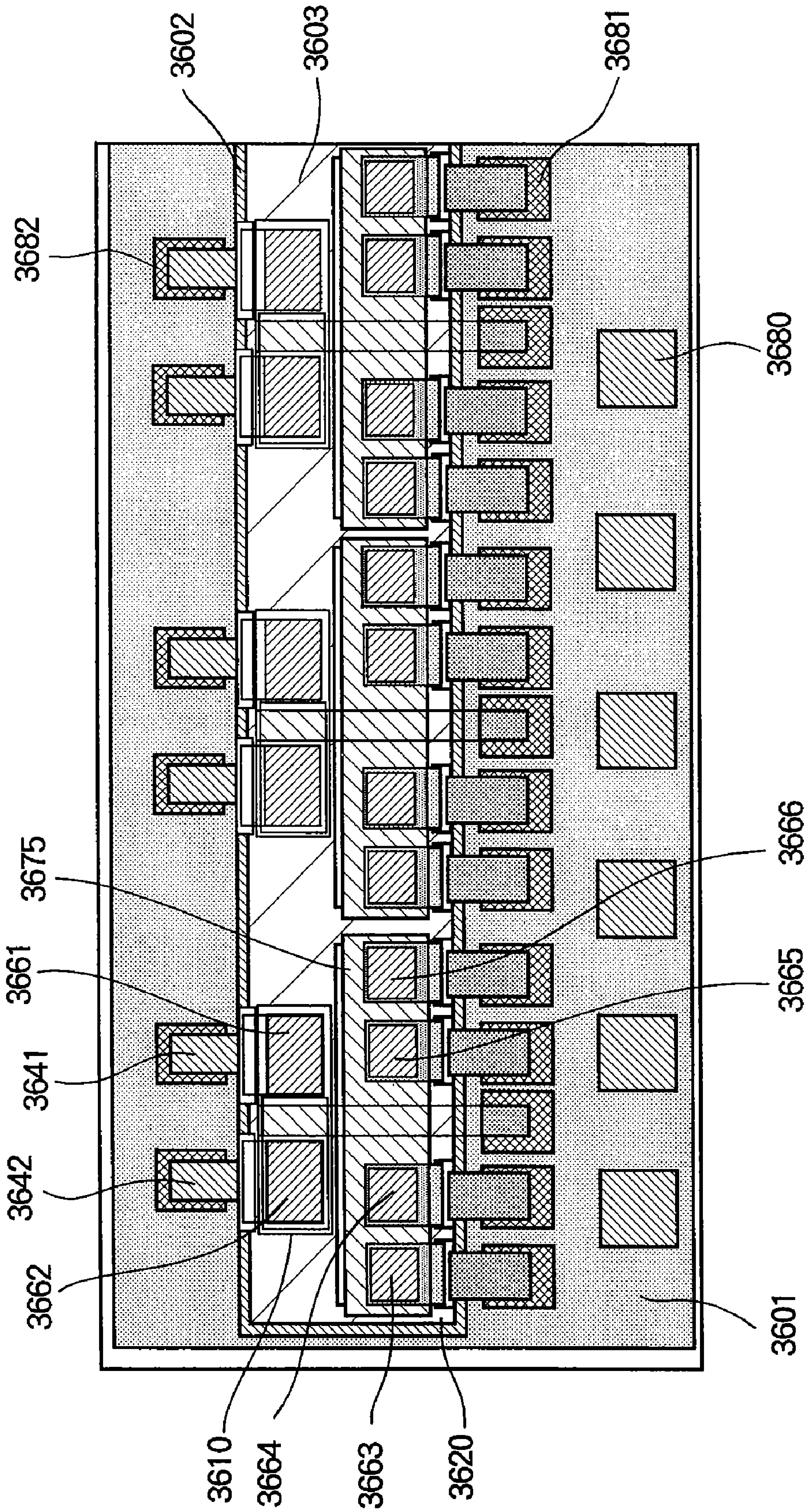
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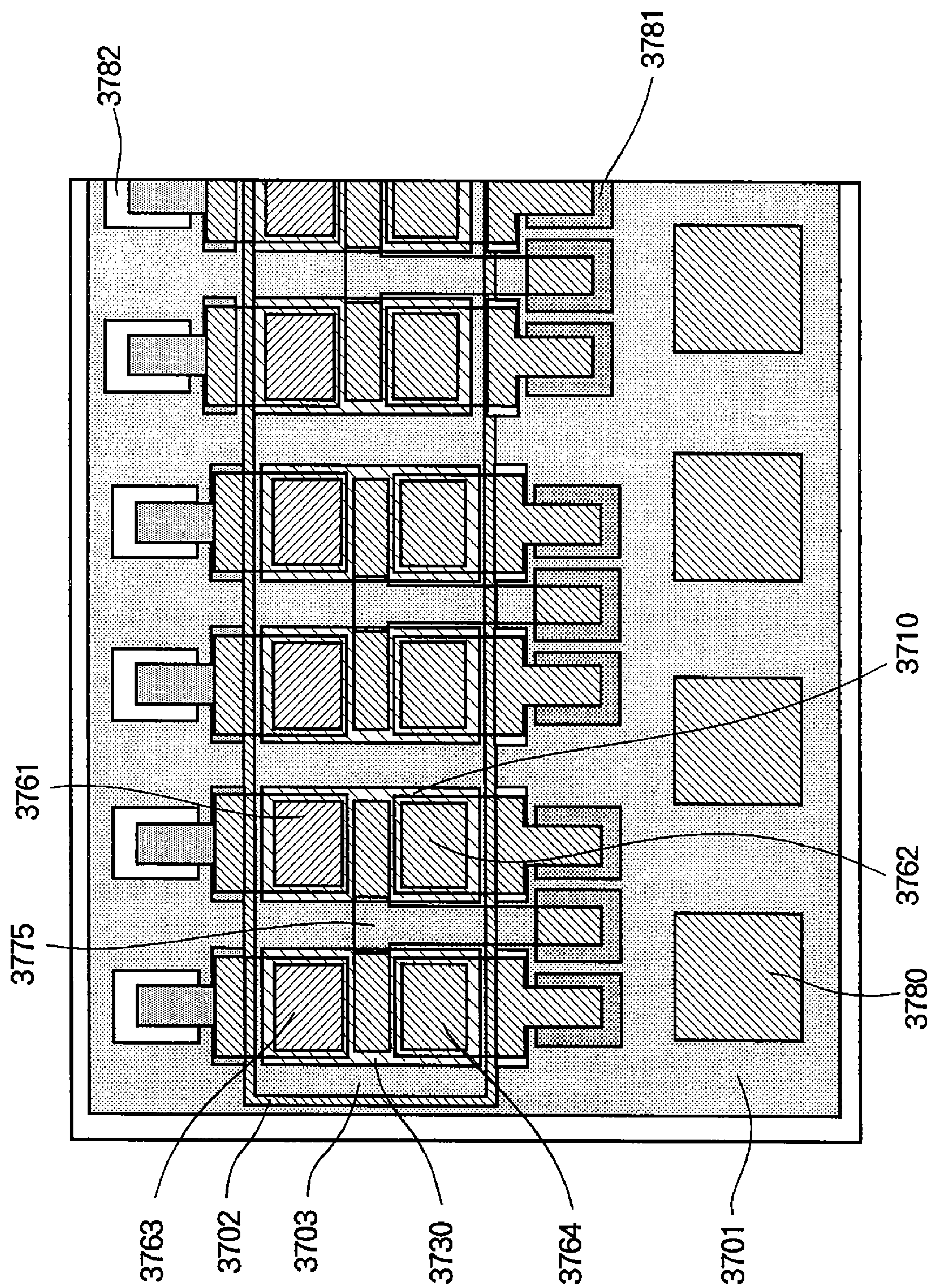
FIG. 48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COMPOSITE SEMICONDUCTOR LIGHT-EMITTING DEVICE

BACKGROUND OF THE INVENTION

This invention relates to a composite semiconductor light-emitting device on which a plurality of light-emitting regions are formed using compound semiconductor layers. Particularly, this invention relates to a composite semiconductor light-emitting device capable of emitting lights of different wavelengths.

There is known a light-emitting diode (LED) capable of emitting lights of different wavelengths. Such a conventional light-emitting diode includes a first light-emitting layer sandwiched between a p-type compound semiconductor epitaxial layer and an n-type compound semiconductor epitaxial layer, and a second light-emitting layer sandwiched between two compound semiconductor layers (containing impurities) whose conductivity types are the same as one of the p-type compound semiconductor layer and the n-type compound semiconductor layer. The second light-emitting layer emits the light whose wavelength is longer than the light emitted by the first light-emitting layer. Such a conventional light-emitting diode is disclosed in, for example, Japanese Laid-Open Patent Publication No. 2001-7401. The light-emitting diode is known as a compound semiconductor light-emitting element that emits white light, which is suitable for a lighting device used in various kinds of display devices such as a backlight of an LCD display device.

The light-emitting element (disclosed in the above described publication) has a layered structure including a single crystal ZnSe substrate (i.e., a lower light-emitting layer) that emits the light upon self-excitation and a ZnSe-based compound semiconductor layer layered on the substrate. A light-emitting layer (i.e., an intermediate light-emitting layer) composed of ZnSeTe and cladding layers sandwiching the intermediate light-emitting layer are formed on the compound semiconductor layer. Another light-emitting layer (i.e., an uppermost light-emitting layer) composed of ZnSe/ZnCdSe multi-quantum well is formed on the upper cladding layer. The uppermost light-emitting layer emits the light of cyan whose wavelength is 480 nm, the intermediate light-emitting layer emits the light of green whose wavelength is 515 nm, and the ZnSe substrate emits the light of yellow.

However, in the layered structure including the semiconductor layers and the substrate that emit lights of different wavelengths as disclosed in the above described publication, it is necessary to match the lattice constants of the layered semiconductor materials to each other, and therefore the kinds of semiconductor materials that can be used are limited. To be more specific, on the single crystal ZnSe substrate, it is possible to grow the same ZnSe-based compound semiconductor layers, but it is difficult to continuously grow a GaN-based semiconductor layer (capable of emitting blue or green light) and a GaAs-based semiconductor layer (capable of emitting red light) on the crystal substrate in terms of lattice constants.

Further, even if it becomes possible to emit lights of the respective wavelengths, there is a case where the intensity of one of the lights of respective wavelengths is weak. In order to uniformly balance the intensities of the lights of respective wavelengths, the intensities of the whole lights must decrease.

SUMMARY OF THE INVENTION

An object of the present invention is to provide a composite semiconductor light-emitting device capable of removing limitations when light-emitting elements emitting lights of different wavelengths are layered, capable of efficiently emitting light, and enabling easy control of the colors of the lights.

The present invention provides a composite semiconductor light-emitting device including a first semiconductor element portion including a first semiconductor material and having a first semiconductor layered structure, and a second semiconductor element portion including a second semiconductor material different from the first semiconductor materials and having a second semiconductor layered structure. The first semiconductor element portion has a plurality of light-emitting regions that emit lights of different wavelengths. The second semiconductor element portion has at least a light-emitting region that emits light whose wavelength is different from the light emitted by the light-emitting regions of the first semiconductor substrate. The light-emitting regions of the first semiconductor element portion and at least one light-emitting region of the second semiconductor element portion are electrically connected to each other.

With such an arrangement, it becomes possible to form a plurality of semiconductor light-emitting regions composed of materials of a plurality of groups, and therefore it becomes possible to enhance the efficiency of light-emission, while maintaining the balance of the intensities of the lights of respective wavelengths. In particular, in the case where the combination of the nitride-based semiconductor material and the GaAs-based semiconductor material or the like is used, it becomes possible to obtain the stable light-emission, which is useful in the lighting units of various kinds of display devices, particularly, the backlight of the LCD display device.

BRIEF DESCRIPTION OF THE DRAWINGS

In the attached drawings:

FIG. **1** is a plan view of a composite semiconductor light-emitting device according to the first embodiment of the present invention;

FIG. **2** is a sectional view of the composite semiconductor light-emitting device of the first embodiment of the present invention, taken along line **2-2** in FIG. **1**;

FIG. **3** is a sectional view of a first example of an element structure applicable to the composite semiconductor light-emitting device of the first embodiment of the present invention;

FIG. **4** is a sectional view of a second example of an element structure applicable to the composite semiconductor light-emitting device of the first embodiment of the present invention;

FIG. **5** is a sectional view of a third example of an element structure applicable to the composite semiconductor light-emitting device of the first embodiment of the present invention;

FIG. **6** is a sectional view of a fourth example of an element structure applicable to the composite semiconductor light-emitting device of the first embodiment of the present invention;

FIG. **7** is a sectional view of a fifth example of an element structure applicable to the composite semiconductor light-emitting device of the first embodiment of the present invention;

FIG. **8** is a sectional view of a sixth example of an element structure applicable to the composite semiconductor light-emitting device of the first embodiment of the present invention;

FIG. **9** is a sectional view of a seventh example of an element structure applicable to the composite semiconductor light-emitting device of the first embodiment of the present invention;

FIG. **10** is a sectional view of a tenth example of an element structure applicable to the composite semiconductor light-emitting device of the first embodiment of the present invention;

FIG. **11** is a plan view of a modification of electrodes and wirings of the composite semiconductor light-emitting device of the first embodiment of the present invention;

FIG. **12** is a plan view of another modification of electrodes and wirings of the composite semiconductor light-emitting device of the first embodiment of the present invention;

FIG. **13** is a plan view of still another modification of electrodes and wirings of the composite semiconductor light-emitting device of the first embodiment of the present invention;

FIG. **14** is a plan view of yet another modification of electrodes and wirings of the composite semiconductor light-emitting device of the first embodiment of the present invention;

FIG. **15** is a plan view of a further modification of electrodes and wirings of the composite semiconductor light-emitting device of the first embodiment of the present invention;

FIG. **16** is a plan view of a composite semiconductor light-emitting device according to the second embodiment of the present invention;

FIG. **17** is a sectional view of the composite semiconductor light-emitting device according to the second embodiment of the present invention, taken along line **17**-**17** in FIG. **16**;

FIG. **18** is a plan view of a composite semiconductor light-emitting device according to the third embodiment of the present invention;

FIG. **19** is a sectional view of the composite semiconductor light-emitting device according to the third embodiment of the present invention, taken along line **19**-**19** in FIG. **18**;

FIG. **20** is a plan view of a modification of the composite semiconductor light-emitting device of the third embodiment of the present invention;

FIG. **21** is a sectional view of the composite semiconductor light-emitting device of FIG. **20**, taken along line **21**-**21** in FIG. **20**;

FIG. **22** is a plan view of another modification of the composite semiconductor light-emitting device of the third embodiment of the present invention;

FIG. **23** is a sectional view of the composite semiconductor light-emitting device of FIG. **22**;

FIG. **24** is a plan view of a still another modification of the composite semiconductor light-emitting device of the third embodiment of the present invention;

FIG. **25** is a plan view of yet another modification of the composite semiconductor light-emitting device of the third embodiment of the present invention;

FIG. **26** is a plan view of a modification of a wiring arrangement of the composite semiconductor light-emitting device of the third embodiment of the present invention;

FIG. **27** is a plan view of another modification of the wiring arrangement of the composite semiconductor light-emitting device of the third embodiment of the present invention;

FIG. **28** is a plan view of still another modification of the wiring arrangement of the composite semiconductor light-emitting device of the third embodiment of the present invention;

FIG. **29** is a plan view of yet another modification of the wiring arrangement of the composite semiconductor light-emitting device of the third embodiment of the present invention;

FIG. **30** is a plan view of a composite semiconductor light-emitting device according to the fourth embodiment of the present invention;

FIG. **31** is a sectional view of the composite semiconductor light-emitting device according to the fourth embodiment of the present invention, taken along line **31**-**31** in FIG. **30**;

FIG. **32** is a sectional view of the composite semiconductor light-emitting device according to the fourth embodiment of the present invention, taken along line **32**-**32** in FIG. **30**;

FIG. **33** is a plan view of a modification of a wiring arrangement of light-emitting regions included in the respective semiconductor element portions of the composite semiconductor light-emitting device of the fourth embodiment of the present invention;

FIG. **34** is a plan view of another modification of the wiring arrangement of the light-emitting regions included in the respective semiconductor element portions of the composite semiconductor light-emitting device of the fourth embodiment of the present invention;

FIG. **35** is a plan view of still another modification of the wiring arrangement of the light-emitting regions included in the respective semiconductor element portions of the composite semiconductor light-emitting device of the fourth embodiment of the present invention;

FIG. **36** is a plan view of yet another modification of the wiring arrangement of the light-emitting regions included in the respective semiconductor element portions of the composite semiconductor light-emitting device of the fourth embodiment of the present invention;

FIG. **37** is a plan view of a further modification of the wiring arrangement of the light-emitting regions included in the respective semiconductor element portions of the composite semiconductor light-emitting device of the fourth embodiment of the present invention;

FIG. **38** is a plan view of still further modification of the wiring arrangement of the light-emitting regions included in the respective semiconductor element portions of the composite semiconductor light-emitting device of the fourth embodiment of the present invention;

FIG. **39** is a plan view of a composite semiconductor light-emitting device according to the fifth embodiment of the present invention;

FIG. **40** is a sectional view of the composite semiconductor light-emitting device according to the fifth embodiment of the present invention, taken along line **40**-**40** in FIG. **39**;

FIG. **41** is a sectional view of the composite semiconductor light-emitting device according to the fifth embodiment of the present invention, taken along line **41**-**41** in FIG. **39**;

FIG. **42** is a schematic plan view of a composite semiconductor light-emitting device according to the sixth embodiment of the present invention;

FIG. **43** is a schematic plan view of a modification of the composite semiconductor light-emitting device according to the sixth embodiment of the present invention;

FIG. **44** is a plan view of a composite semiconductor light-emitting device according to the seventh embodiment of the present invention;

FIG. **45** is a sectional view of the composite semiconductor light-emitting device according to the seventh embodiment of the present invention, taken along line **45-45** in FIG. **44**;

FIG. **46** is a sectional view of the composite semiconductor light-emitting device according to the seventh embodiment of the present invention, taken along line **46-46** in FIG. **45**;

FIG. **47** is a schematic plan view of a composite semiconductor light-emitting device according to the eighth embodiment of the present invention; and

FIG. **48** is a schematic plan view of a composite semiconductor light-emitting device according to the ninth embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Embodiments of the present invention will be described with reference to the attached drawings.

Embodiment 1

FIG. **1** is a plan view schematically showing a composite semiconductor light-emitting device according to the first embodiment of the present invention. FIG. **2** is a sectional view taken along line **2-2** in FIG. **1**.

As shown in FIG. **2**, the composite semiconductor light-emitting device of the first embodiment includes a substrate **101**, a metal layer **102** (that functions as a reflection film) formed on the substrate **101** and a first dielectric layer **103** formed on the metal layer **102**. A first semiconductor element portion **110** is formed on the first dielectric layer **103**, and a second semiconductor element portion **130** is formed on the first semiconductor element portion **110**. The first semiconductor element portion **110** has a first semiconductor layered structure, and includes first and second light-emitting regions. The second semiconductor element portion **130** has a second semiconductor layered structure, and includes a third light-emitting region. The first semiconductor layered structure is made of first semiconductor materials, and particularly, GaN-based nitride semiconductor materials such as GaN, $Al_xGa_{1-x}N$, $Ga_xIn_{1-x}N$. The second semiconductor layered structure is made of second semiconductor materials (of a group different from the first semiconductor materials), and particularly, semiconductor materials such as $Al_xGa_yIn_{1-x-y}P$ and $Al_xGa_{1-x}As$.

The structure of the first semiconductor element portion **110** will be described. First, an n-type GaN layer **110**a is formed on the first dielectric layer **103**. A first light-emitting layer **110**b is formed on the n-type GaN layer **110**a. The first light-emitting layer **110**b includes a GaInN/GaN multi-quantum well layer and a p-type AlGaN layer. A p-type GaN layer **110**c is formed on the first light-emitting layer **110**b. The n-type GaN layer **110**a, the first light-emitting layer **110**b and the p-type GaN layer **110**c constitute a first light-emitting region, on which a second light-emitting region is formed.

The second light-emitting region includes an n-type GaN layer **110**d formed on the p-type GaN layer **110**c, a second light-emitting layer **110**e (including a GaInN/GaN multi-quantum well layer and a p-type AlGaN layer) formed on the n-type GaN layer **110**d and a p-type GaN layer **110**f formed on the second light-emitting layer **110**e. InN mole fraction of the second light-emitting layer **110**e is smaller than that of the first light-emitting layer **110**b. The above described layers are covered by a second dielectric layer **140**. Openings are formed on the second dielectric layer **140** where contacts are to be formed.

The wavelength of the light emitted by the first light-emitting layer **110**b is, for example, 515 nm (i.e., green). The wavelength of the light emitted by the second light-emitting layer **110**e is, for example, 460 nm (i.e., blue). Thus, in the composite semiconductor light-emitting device according to the first embodiment, it is possible to obtain the lights of different wavelengths emitted by the semiconductor layered structures.

The structure of the second semiconductor element portion **130** will be described. The second semiconductor element portion **130** is made of GaAs-based III-V compound semiconductor materials, and includes an n-type $Al_xGa_{1-x}As$ layer **130**a formed on the second dielectric layer **140**, an n-type GaAs layer **130**b formed on the n-type $Al_xGa_{1-x}As$ layer **130**a, a third light-emitting layer **130**c (including semiconductor layers of an n-type $Al_yGa_{1-y}As$ cladding layer, an n-type $Al_zGa_{1-z}As$ active layer and a p-type $Al_tGa_{1-t}As$ cladding layer) formed on the n-type GaAs layer **130**b, and a p-type GaAs layer **130**d formed on the third light-emitting layer **130**c. The wavelength of the light emitted by the third light-emitting layer **130**c of the second semiconductor element portion **130** is, for example, 750 nm. Alternatively, it is possible use $(Al_xGa_{1-x})_yIn_{1-y}P$ based materials, to thereby obtain the emission of the red light whose wavelength is approximately 650 nm. The second semiconductor element portion **130** is, for example, wholly bonded onto the second dielectric layer **140**.

Metal wirings **105** and **107** electrically connect n-side contact layers and p-side contact layers of the respective light-emitting regions. In particular, the metal wiring **105** electrically connects the first light-emitting region and the second light-emitting region, i.e., electrically connects the p-type GaN layer **110**c and n-type GaN layer **110**d. The metal wiring **107** electrically connects the second light-emitting region and the second semiconductor element portion **130**, i.e., electrically connects the p-type GaN layer **110**f and the n-type GaAs layer **130**b of the second semiconductor element portion **130**. As shown in FIG. **1**, an n-side electrode pad **141** and a p-side electrode pad **143** are provided on both sides of the main part of the composite semiconductor light-emitting device. Each of the n-side electrode pad **141** and the p-side electrode pad **143** substantially has a rectangular shape. The electrode pads **141** and **143** is supplied with current by performing wire-bonding or forming wirings thereon. As shown in FIG. **2**, a metal wiring **108** electrically connects the n-side electrode pad **141** and the n-type GaN layer **110**a. A metal wiring **106** electrically connects the p-side electrode pad **143** and a transparent conductive layer **109** (i.e., a transparent electrode) formed as an uppermost layer covering the p-type GaAs layer **130**d. In this regard, instead of the transparent electrode **109**, it is possible to use a metal contact that partially covers the upper surface of the p-type GaAs layer **130**d. As shown in FIGS. **1** and **2**, the first light-emitting region, the second light-emitting region and the third light-emitting region are electrically connected in series with each other.

The first and second semiconductor element portions **110** and **130** (FIG. **2**) are formed by growing semiconductor layered structures on different substrates, and separating (peeling off) the semiconductor layered structures from the respective substrates. The first and second semiconductor element portions **110** and **130** are bonded to each other on the substrate **101**. Particularly, the second semiconductor element portion **130** is bonded onto the first semiconductor element portion **110**. The first semiconductor element portion **110** is bonded onto, for example, the first dielectric layer **103** provided for bonding. The second semiconductor element portion **130** is bonded to, for example, the second dielectric layer **140** provided for bonding. A metal layer **102** is formed below the first and second semiconductor element portions (for example, below the first dielectric layer **103**). The lights emitted downward from the respective light-emitting regions are reflected upward by the metal layer **102**, and therefore the amount of the emitted light can be enhanced.

The semiconductor layered structure shown in FIGS. **1** and **2** is an example, and it is also possible to employ other semiconductor layered structures. FIGS. **3** through **6** show examples of the semiconductor layered structure of the nitride compound semiconductor.

FIG. **3** shows a semiconductor layered structure (including the light-emitting region) formed by layering an n-type GaN layer **304**, an InGaN/GaN multi-quantum well layer **305**, a p-type AlGaN layer **306**, and a p-type GaN layer **307**. For example, in relation to FIG. **2**, the first light-emitting layer **110***b* or the second light-emitting layer **110***e* of FIG. **2** corresponds to the layered structure of the InGaN/GaN multi-quantum well layer **305** and the p-type AlGaN layer **306**. The InGaN/GaN multi-quantum well layer **305** includes an InGaN layer **305***a*, a layered structure **305***b* formed on the InGaN layer **305***a*, and an InGaN layer **305***c* formed on the layered structure **305***b*. The layered structure **305***b* includes layers of GaN/InGaN/GaN/InGaN . . . /GaN/InGaN/GaN.

FIG. **4** shows a semiconductor layered structure (including the light-emitting regions) formed by layering an n-type GaN layer **402**, an n-type $Al_xGa_{1-x}As$ layer **403**, an $Al_yGa_{1-y}As$ layer **404**, a p-type $Al_zGa_{1-z}As$ layer **405**, and p-type GaN layer **406**. In relation to FIG. **2**, the first light-emitting layer **110***b* or the second light-emitting layer **110***e* of FIG. **2** corresponds to the layered structure of the n-type $Al_xGa_{1-x}As$ layer **403**, the $Al_yGa_{1-y}As$ layer **404** and the p-type $Al_zGa_{1-z}As$ layer **405**.

FIG. **5** shows a semiconductor layered structure (including the light-emitting regions) formed by layering an n-type GaN layer **502**, a Zn-doped or Si-doped GaN layer **503**, a Mg-doped p-type AlGaN layer **504** and a Mg-doped p-type GaN layer **505**. In relation to FIG. **2**, the first light-emitting layer **110***b* or the second light-emitting layer **110***e* of FIG. **2** corresponds to the layered structure of the Zn-doped or Si-doped GaN layer **503** and the Mg-doped p-type AlGaN layer **504**.

FIG. **6** shows a semiconductor layered structure formed by layering an n-type GaN layer **602** and a p-type GaN layer **603**. In relation to FIG. **2**, the first light-emitting layer **110***b* or the second light-emitting layer **110***e* of FIG. **2** corresponds to the layered structure of the n-type GaN layer **602** and the p-type GaN layer **603**.

Next, other examples of the structure of GaAs-based layers will be described with reference to FIGS. **7** through **10**.

FIG. **7** shows a semiconductor layered structure formed by layering an n-type GaAs layer **701**, an n-type layer **702**, an n-type GaAs layer **703**, an $In_rGa_{1-r}P$ layer **704**, an n-type $Al_xGa_{1-x}As$ layer **705**, an n-type $Al_yGa_{1-y}As$ layer **706**, a p-type $Al_zGa_{1-z}As$ layer **707**, and a p-type GaAs layer **708** (x, z≧y and 0≦y, r≦1). In relation to FIG. **2**, the second semiconductor element portion **130** of FIG. **2** corresponds to the layered structure of the layers **701** through **708** of FIG. **7**.

FIG. **8** shows a semiconductor layered structure formed by layering an n-type GaAs layer **801**, an n-type $Al_xGa_{1-x}As$ layer **802**, an n-type $Al_yGa_{1-y}As$ layer **803**, a p-type Al_zGa_{1-z} As layer **804** and a p-type GaAS layer **805** (x, z≧y and 0≦y≦1). In relation to FIG. **2**, the second semiconductor element portion **130** of FIG. **2** corresponds to the layered structure of the layers **801** through **805** of FIG. **8**.

FIG. **9** shows a semiconductor layered structure formed by layering an n-type GaAs layer **901**, an n-type $Al_yGa_{1-y}As$ layer **902**, a p-type $Al_zGa_{1-z}As$ layer **903** and a p-type GaAs layer **904** (z≧y and 0≦y≦1). In relation to the semiconductor layered structure shown in FIG. **2**, the second semiconductor element portion **130** of FIG. **2** corresponds to the layered structure of the layers **901** through **904** of FIG. **9**.

FIG. **10** shows a semiconductor layered structure made of AlGaInP-based materials. The semiconductor layered structure of FIG. **10** includes an n-type GaAs layer **1001**, an n-type $Al_rGa_{1-r}As$ or n-type $(Al_sGa_{1-s})_uIn_{1-u}As$ conductive layer **1002**, an n-type GaAs contact layer **1003**, an $In_vGa_{1-v}P$ etching stopper layer **1004**, an n-type AlGaInP cladding layer **1005**, a GaInP active layer **1006**, a p-type AlGaInP cladding layer **1007**, a p-type GaInP layer **1008** and a p-type GaAs layer **1009**. In relation to FIG. **2**, the second semiconductor element portion **130** of FIG. **2** corresponds to the layered structure of the layers **1001** through **1009** of FIG. **10**.

In the semiconductor layered structure shown in FIG. **10**, the light-emitting region (i.e., the n-type AlGaInP cladding layer **1005**, the GaInP active layer **1006** and the p-type AlGaInP cladding layer **1007**) can be of lattice-matched hetero-layered structure such as $Ga_{0.5}In_{0.5}P/(Al_xGa_{1-x})_{0.5}P$, or strained $Ga_xIn_{1-x}P$ quantum structure. Further, the light-emitting region can be of single quantum well (SQW) structure, or multi-quantum well (MQW) structure. In the lattice-matched structure, the mixed crystal ratio can deviate from the ideal value (i.e., 0.5). For example, $Ga_{0.52}In_{0.48}P$ can be used. In the above described examples, the semiconductor layered structure can be appropriately modified.

The semiconductor layered structures of the above described materials have thin-film structures. The semiconductor layered structure can be formed by forming a releasing layer on a substrate, layering the semiconductor epitaxial layers of the respective composition to grow the epitaxial semiconductor layered structure, removing the releasing layer by means of an etching solution (that selectively causes the releasing layer to solve), and separating the semiconductor layered structure from the substrate. The thickness of the semiconductor layered structure is preferably less than or equals to 10 μm, and more preferably less than or equals to 2 μm. With such a thickness, the height of each layer can be reduced, and therefore the disconnection of the wirings can be prevented.

In the composite semiconductor light-emitting device according to the first embodiment, three kinds of light-emitting regions are electrically connected in series with each other. By allowing the current to flow between the n-side electrode pad **141** and the p-side electrode pad **143**, the first, second and third light-emitting regions are activated to emit light.

In the above described first embodiment, GaN-based semiconductor emits the light whose wavelength is relatively short (i.e., blue and green), the GaAs-based semiconductor emits the light whose wavelength is relatively long (i.e., red) that is difficult for the GaAs-based semiconductor to emit, and the semiconductors are bonded to each other. Therefore, it becomes possible to obtain the lights whose wavelengths are suitable for the respective semiconductors. By combining the lights of the primary colors, it becomes possible to obtain the light of the preferable color (for example, white light) of high intensity.

That is, in the composite semiconductor light-emitting device of the first embodiment of the present invention, a first semiconductor element portion **110** (that emit the lights of a plurality of wavelengths) made of the layered structure of the semiconductor materials of the same group, and a second semiconductor element portion **130** made of the layered structure of the different semiconductor materials are integrated. Therefore, it becomes possible to obtain the composite semiconductor light-emitting device (that emits the lights of a plurality of wavelengths) which occupies less space and which is excellent in controllability of light-emission property or color, and the combination of the wavelengths of the lights is not limited by lattice-constant or heat expansion coefficient of the materials.

Further, in the first embodiment, the second semiconductor element portion **130** (of the GaAs-based layers) is bonded onto the first semiconductor element portion **110** (of the GaN-based layers) via the dielectric layer **140**. However, the second semiconductor element portion **130** can be directly bonded onto the first semiconductor element portion **110**. Alternatively, the second semiconductor element portion **130** can be bonded onto the first semiconductor layer **110** via a metal layer. By bonding the second semiconductor element portion **130** (of the GaAs-based layers) to the first semiconductor element portion **140** (of the GaN-based layers) directly or via metal layer, it becomes unnecessary to connect the metal wiring **107** to both of the p-type GaN layer **110***f* and the n-type GaAs layer **130***b*. In such a case, it is possible to connect the metal wiring **107** to one of the p-type GaN layer **110***f* and the n-type GaAs layer **130***b*.

As described above, the semiconductor light-emitting device (in which the light-emitting regions corresponding to the plurality of colors are integrated) can be configured to emit the lights of desired wavelengths at desired intensities. Therefore, the semiconductor light-emitting device can be employed in various kinds of lighting devices such as a white backlight or flashlight. In this regard, if the conventional light-emitting device (LED) that emits the light of long wavelength is used in combination with a fluorescent coating, the light emitted by the LED is absorbed by the fluorescent coating and converted into the light of different wavelength, and therefore the conversion efficiency is low and the output intensity is reduced to a large extent. However, according to the first embodiment of the present invention, the lights of the desired wavelengths are directly emitted, and therefore the white light of high intensity can be emitted.

In the composite semiconductor light-emitting device according to the first embodiment of the present invention, the combination of the lights emitted by the respective light-emitting regions is not limited to the combination that produces white light. It is also possible to produce light of various colors for many purposes, by selecting the wavelengths and the intensities of the lights.

Modifications may be made to the first embodiment of the present invention in terms of material and structure. The modifications will be described hereinafter.

FIGS. **11** and **12** are plan views showing modifications to arrangements of the electrodes and the wirings. In FIGS. **11** and **12**, the modification is made to the wiring **107** electrically connecting the first semiconductor element portion **110** and the second semiconductor element portion **130**. In an example shown in FIG. **11**, a wiring **107***a* is configured to form three sides of a rectangle, and electrically connects the first semiconductor element portion **110** and the second semiconductor element portion **130**. In another example shown in FIG. **12**, a writing **107***b* is configured to form four sides of a rectangle, and electrically connects the first semiconductor element portion **110** and the second semiconductor element portion **130**. With such configurations, it becomes possible to prevent the concentration of the current in the vicinity of the electrode, and therefore the distribution of the light emitted from the second semiconductor element portion **130** becomes uniform.

FIGS. **13** through **15** are plan views showing the modifications of the wiring that electrically connects the first light-emitting region and the second light-emitting region. In an example shown in FIG. **13**, a wiring **105***a* connecting two light-emitting regions of the first semiconductor element portion **110** is configured to surround the rectangular first and second semiconductor element portions **110** and **130** on four sides. With such a configuration, it becomes possible to prevent the concentration of the current in the vicinity of the electrode, and therefore the distribution of the light emitted from the first semiconductor element portion **110** becomes uniform.

In an example shown in FIG. **14**, a pair of wirings **105***b* that electrically connect two light-emitting regions of the first semiconductor element portion **110** are disposed on two opposing sides of a rectangle. A pair of wirings **108***b* that electrically connect the n-side electrode pad **141** and the n-type GaN layer **110***a* of the first semiconductor element portion **110** are disposed on the other two opposing sides of the rectangle. With such a layout, the current is allowed to flow through the first semiconductor element portion **110** in a symmetrical manner, and it becomes possible to prevent the concentration of the current in the vicinity of the electrode. Therefore, the distribution of the light emitted from the first semiconductor element portion **110** becomes uniform.

In an example shown in FIG. **15**, a wiring **105***c* that electrically connects two light-emitting regions of the first semiconductor element portion **110** is disposed on one side of a rectangular. A wiring **108***c* that electrically connect the n-side electrode pad **141** and the n-type GaN layer **110***a* of the first semiconductor element portion **110** is disposed on the opposite side of the rectangular. With such a layout, the current is allowed to flow through the first semiconductor element portion **110** in a symmetrical manner, and it becomes possible to prevent the concentration of the current in the vicinity of the electrode. Therefore, the distribution of the light emitted from the first semiconductor element portion **110** becomes uniform.

Furthermore, it is also possible to provide a metal layer below the second semiconductor element portion **130**, i.e., on the top of the first semiconductor element portion **110** or below the second dielectric layer **140**, for enhancing the effect of the reflection of the light in the third light-emitting region. With such a configuration, it is possible to increase the intensity of the light emitted from the third light-emitting region. Moreover, a part of the light emitted by the first and second light-emitting regions is reflected by the metal layer on the top of the first semiconductor element portion **110**, and further reflected by the metal layer **102** at the bottom of the first semiconductor element portion **110** (or the reflection of the light is repeated), and therefore the intensity of the light emitted from the top of the device can be enhanced.

In the above described first embodiment, the second semiconductor element portion (i.e., second semiconductor layered structure) **130** has been described to include one light-emitting region. However, it is also possible to configure the second semiconductor element portion **130** to include a plurality of light-emitting regions, and to connect the respective light-emitting regions in series with each other as in the first semiconductor element portion (i.e., first semiconductor layered structure) **110**. With such an arrangement, it becomes possible to increase the amount of the light emitted by the second semiconductor element portion **130**.

Besides the above described semiconductor materials, it is also possible to use one of or any combination of the following nitride-based semiconductor materials: $GaAs_{1-x-y}As_xN_x$, $GaP_{1-x}N_x$, $InAs_{1-x}N_x$, $InGa_{1-x}As_{1-y}N_y$, $InP_{1-x-y}As_xN_y$, $GaP_{1-x-y}As_xN_y$, $In_xAl_{1-x}N$ ($1 \geqq x \geqq 0$, and $1 \geqq y \geqq 0$). Further, it is also possible to use quarternary material such as Al_x

$Ga_yAs_{1-x-y}P$, $Al_xGa_yIn_{1-x-y}P$ or the like. It is also possible to use II-VI compound semiconductor materials, or oxide semiconductor material such as ZnO.

The substrate **101** can be made of quarts, glass, metal, organizing material such as PET (Poly-Ethylene-Terephthalate) or PI (Polyimide), semiconductor such as Si or SiC, ceramic or other various kinds of material. The substrate **101** can be a thick plate, or a thin plate having a flexibility.

Second Embodiment

FIG. **16** is a plan view schematically showing a composite semiconductor light-emitting device according to the second embodiment of the present invention. FIG. **17** is a sectional view taken along line **17-17** in FIG. **16**. The second embodiment is different from the first embodiment in that a first semiconductor element portion **1110** is formed on a second semiconductor element portion **1130**. Here, the description is focused on features of the second embodiment different from the first embodiment.

As shown in FIG. **17**, in the composite semiconductor light-emitting device of the second embodiment, the second semiconductor element portion **1130** (having the third light-emitting region) is formed below the first semiconductor element portion **1110** (having the first and second light-emitting regions). The second semiconductor element portion **1130** is made of GaAs-based semiconductor materials. In particular, an n-type $Al_xGa_{1-x}As$ layer **1130***a* is formed on the dielectric layer **103**, an n-type GaAs layer **1130***b* is formed on the $Al_xGa_{1-x}As$ layer **1130***b*, and a third light-emitting layer **1130***c* (including an n-type $Al_yGa_{1-y}As$ cladding layer, an n-type $Al_zGa_{1-z}As$ active layer and a p-type $Al_tGa_{1-t}As$ cladding layer) is formed on the n-type GaAs layer **1130***b*. A p-type GaAs layer **1130***d* is formed on the third light-emitting layer **1130***c*.

The first semiconductor element portion **1110** is formed on the second semiconductor element portion **1130** made of GaAs-based materials. The first semiconductor element portion **1110** is made of nitride compound semiconductor material, and has the first and second light-emitting regions that emit lights of different wavelengths. To be more specific, an n-type GaN layer **1110***a* is formed on the interlaminar dielectric layer **140**, and a first light-emitting layer **1110***b* (including a GaInN/GaN multi-quantum well layer and a p-type AlGaN layer) is formed on the N-type GaN layer **1110***a*. A p-type GaN layer **1110***c* is formed on the first light-emitting layer **1110***b*. The layers **1110***a*, **1110***b* and **1110***c* constitute a first light-emitting region, on which a second light-emitting region is formed. The second light-emitting region includes an n-type GaN layer **1110***d*, a second light-emitting layer **1110***e* (including a GaInN/GaN multi-quantum well layer and a p-type AlGaN layer) formed on the n-type GaN layer **1110***d*, and a p-type GaN layer **1110***f* formed on the second light-emitting layer **1110***e*. InN mole fraction of the second light-emitting layer **1110***e* is smaller than that of the first light-emitting layer **1110***b*.

The plurality of light-emitting regions are electrically connected in series with each other as was described in the first embodiment. It is also possible to use the respective semiconductor layered structures and respective light-emitting regions described in the first embodiment. Further, it is possible to employ the modifications described in the first embodiment.

In the second embodiment, the wavelength of the light emitted by the third light-emitting region of the second semiconductor element portion **1130** can be set longer than the wavelengths of the lights emitted by the first and second light-emitting regions of the first semiconductor element portion **1110**. With such an arrangement, the light emitted upward from the second semiconductor element portion **1130**, the light emitted downward from the second semiconductor element portion **1130** and reflect upward at the bottom (i.e., the metal layer **102**), and the light repeatedly reflected between the top and bottom and finally directed upward are not absorbed by the first semiconductor element portion **1110** when the lights pass the first semiconductor element portion **1110**. Therefore, the intensity of the light emitted by the second semiconductor element portion **1130** can be increased relative to the light emitted by the first semiconductor element portion **1110**.

According to the second embodiment of the present invention, the second semiconductor element portion **1130** having the third light-emitting region is formed below the first semiconductor element portion **1110** having the first and second light-emitting regions. Accordingly, the light emitted upward from the second semiconductor element portion **1130**, the light emitted downward from the second semiconductor element portion **1130** and reflect upward at the bottom, and the light repeatedly reflected between the top and bottom and finally directed upward are not absorbed by the first semiconductor element portion **1110** when the lights pass the first semiconductor element portion **1110**, and therefore the intensity of the light emitted by the second semiconductor element portion **1130** can be increased relative to the light emitted by the first semiconductor element portion **1110**.

Third Embodiment

FIG. **18** is a plan view schematically showing a composite semiconductor light-emitting device according to the third embodiment of the present invention. FIG. **19** is a sectional view taken along line **19-19** in FIG. **18**. The composite semiconductor light-emitting device of the third embodiment is different from that of the first embodiment in that a first semiconductor element portion **1510** and a second semiconductor element portion **1530** are bonded onto different regions in layout.

The light-emitting regions of the first semiconductor element portion **1510** and the light-emitting region of the second semiconductor element portion **1530** are electrically connected in series with each other. Here, the description is focused on features of the third embodiment different from the first and second embodiments.

As shown in FIG. **18**, the first semiconductor element portion **1510** and the second semiconductor element portion **1530** are bonded onto the regions adjacent to each other. A reflection metal layer **1502** is formed on a substrate **1501**. A dielectric film **1503** is formed on the reflection metal layer **1502**, and the first and second semiconductor element portions **1510** and **1530** are formed on the dielectric film **1503**. Electrodes **1551** and **1553** are formed on the tops of the respective semiconductor element portions **1510** and **1530**. The electrodes **1551** and **1553** are made of transparent conductive materials in order to obtain a high efficiency of the light emission. The light-emitting regions of the respective semiconductor element portions **1510** and **1530** are connected in series with each other by means of wirings **1505**, **1555**, **1553** and **1508**. The wiring **1505** is electrically connected to a p-side electrode pad **1542**, and the wiring **1508** is electrically connected to an n-side electrode pad **1541**.

The first semiconductor element portion **1510** and the second semiconductor element portion **1530** can be formed of the structure and materials described in the first embodiment. To be more specific, as shown in FIG. **19**, an n-type GaN layer

1510*a* is formed on the dielectric layer **1503**, and a first light-emitting layer **1510***b* (including a GaInN/GaN multi-quantum well layer and a p-type AlGaN layer) is formed on the N-type GaN layer **1510***a*. A p-type GaN layer **1510***c* is formed on the first light-emitting layer **1510***b*. The layers **1510***a*, **1510***b* and **1510***c* constitute a first light-emitting region, on which a second light-emitting region is formed. The second light-emitting region includes an n-type GaN layer **1510***d*, a second light-emitting layer **1510***e* (including a GaInN/GaN multi-quantum well layer and a p-type AlGaN layer) formed on the n-type GaN layer **1510***d*, and a p-type GaN layer **1510***f* formed on the second light-emitting layer **1510***e*. InN mole fraction of the second light-emitting layer **1510***e* is smaller than that of the first light-emitting layer **1510***b*.

The second semiconductor element portion **1530** is made of GaAs-based semiconductor materials. To be more specific, an n-type $Al_xGa_{1-x}As$ layer **1530***a* is formed on the dielectric layer **1503**, an n-type GaAs layer **1530***b* is formed on the $Al_xGa_{1-x}As$ layer **1530***b*, and a third light-emitting layer **1530***c* (including an n-type $Al_yGa_{1-y}As$ cladding layer, an n-type $Al_zGa_{1-z}As$ active layer and a p-type $Al_tGa_{1-t}As$ cladding layer) is formed on the n-type GaAs layer **1530***b*. A p-type GaAs layer **1530***d* is formed on the third light-emitting layer **1530***c*. Further, the modifications described in the first embodiment can be made to the arrangement of the electrodes and the electrode pads or the like.

The substrate **1501**, the reflection metal layer **1502**, and the first dielectric film **1503** of the third embodiment are respectively the same as the substrate **101**, the reflection metal layer **102** and the first dielectric layer **103** of the first embodiment.

In the third embodiment of the present invention, the light-emitting regions of the first semiconductor element portion **1510** and the light-emitting region of the second semiconductor element portion **1530** are bonded onto different regions, and therefore the manufacturing process can be simplified. Further, the degrees of freedom in design of size and shape increase. Moreover, it becomes possible to remove the influence of the absorption of the light (according to the properties of the semiconductor materials of the respective semiconductor element portions **1510** and **1530**), and therefore it becomes possible to enhance the properties, for example, the efficiency of light emission, the uniformity of the intensities of the lights, or the like.

FIG. **20** is a plan view showing a modification of the composite semiconductor light-emitting device of the third embodiment. FIG. **21** is a sectional view taken along line **21-21** in FIG. **20**. As shown in FIGS. **20** and **21**, the transparent electrodes can be replaced by contact layers **1561** and **1563** respectively formed on the tops of the first and second semiconductor element portions **1510** and **1530**. The contact layers **1561** and **1563** are made of metal. In this case, the contact layers **1561** and **1563** do not cover whole surfaces of the regions from which the lights are emitted, but partially open the surfaces of the regions through which the lights are emitted.

FIG. **22** is a plan view showing another modification of the composite semiconductor light-emitting device of the third embodiment. FIG. **23** is a sectional view taken along line **23-23** in FIG. **22**. As shown in FIGS. **22** and **23**, the second semiconductor element portion **1530** can be bonded onto the semiconductor layer **1510***a* of the first semiconductor element portion **1510**. In this case, a second dielectric film **1540** can be formed below the semiconductor layer **1530***a* of the second semiconductor element portion **1530**.

FIG. **24** is a schematic view showing still another modification of the composite semiconductor light-emitting device of the third embodiment. As shown in FIG. **24**, a first semiconductor element portion **1610** includes semiconductor layers **1610***a*, **1610***b* and **1610***c* (constituting a first light-emitting region), and semiconductor layers **1610***d*, **1610***e* and **1610***f* (constituting a second light-emitting region). A second semiconductor element portion **1630** includes semiconductor layers **1630***a*, **1630***b*, **1630***c* and **1630***d*. The semiconductor layers **1630***a* through **1630***d* of the second semiconductor element portion **1630** are layered, and bonded onto the semiconductor layers **1610***a*, **1610***b* and **1610***c* of the first semiconductor element portion **1610**.

FIG. **25** is a schematic view showing yet another modification of the composite semiconductor light-emitting device of the third embodiment. As shown in FIG. **25**, a second semiconductor element portion **1730** is bonded onto a semiconductor layer **1710***c* of the first semiconductor element portion **1710** via a dielectric layer **1740** as described in the modification shown in FIG. **24**. Further, in FIG. **25**, a semiconductor layer **1710***a* of the first semiconductor element portion **1710** and a semiconductor layer **1730***b* of the second semiconductor element portion **1730** are electrically connected to each other via a metal wiring **1755**.

FIG. **26** is a plan view showing a modification of the wiring arrangement of the third embodiment. FIG. **27** is a plan view showing another modification of the wiring arrangement of the third embodiment. FIG. **28** is a plan view showing still another modification of the wiring arrangement of the third embodiment. FIG. **29** is a plan view showing yet another modification of the wiring arrangement of the third embodiment. As shown in FIGS. **26** through **29**, various modification can be made to the wiring arrangement of the third embodiment in accordance with wiring space.

In an example shown in FIG. **26**, the contact layers **1561** and **1563** extend in the same directions, to form extending portions **1571** and **1573**. In an example shown in FIG. **27**, the contact layers **1561** and **1563** extend in the opposite directions, to form extending portions **1572** and **1574**. In an example shown in FIG. **28**, the wiring **1555** extends to form an extending portion **1575**. In an example shown in FIG. **29**, the first and second semiconductor element portions **1510** and **1530** are arranged side by side, and a wiring **1557** is formed to connect the semiconductor element portions **1510** and **1530**.

Fourth Embodiment

FIG. **30** is a plan view schematically showing a composite semiconductor light-emitting device according to the fourth embodiment of the present invention. FIG. **31** is a sectional view taken along line **31-31** shown in FIG. **30**. FIG. **32** is a sectional view taken along line **32-32** in FIG. **30**. The fourth embodiment is different from the third embodiment in that a first semiconductor element portion **2410** and a second semiconductor element portion **2430** are electrically connected in parallel with each other.

In FIG. **30**, the first semiconductor element portion **2410** and the second semiconductor element portion **2430** are disposed adjacent to each other so that the first semiconductor element portion **2410** is disposed on line **31-31** side, and the second semiconductor element portion **2430** is disposed on line **32-32** side.

As shown in FIG. **31**, a metal layer **2402** that functions as a reflection film is formed on a substrate **2401**, and a first dielectric layer **2403** is formed on the metal layer **2402**. The first semiconductor element portion **2410** of a first semiconductor layered structure (having first and second light-emitting regions) and the second semiconductor element portion **2430** of a second semiconductor layered structure (having a third light-emitting region) are formed on the first dielectric layer **2403**. The first semiconductor element portion **2410** is made of first semiconductor materials. For example, the first semiconductor element portion **2410** is made of GaN-based nitride semiconductor material such as GaN, $Al_xGa_{1-x}N$ and $Al_xGa_{1-x}N$. The second semiconductor element portion **2430** is made of second semiconductor materials of a group different from the first semiconductor materials. For example, the second semiconductor element portion **2430** is made of GaAs-based semiconductor materials such as $Al_xGa_{1-x-y}P$ and $Al_xGa_{1-x}As$.

The structure of the first semiconductor element portion **2410** will be described. A p-type GaN layer **2410***a* is formed on the first dielectric layer **2403**. A first light-emitting layer **2410***b* (including a GaInN/GaN multi-quantum well layer and a p-type AlGaN layer) is formed on the p-type GaN layer **2410***a*. An n-type GaN layer **2410***c* is formed on the first light-emitting layer **2410***b*. The layers **2410***a*, **2410***b* and **2410***c* form a first light-emitting region. A second light-emitting region is formed to have an n-side electrode in common with the first light-emitting region. The second light-emitting region includes an n-type GaN layer **2410***c*, a second light-emitting layer **2410***d* (including a GaInN/GaN multi-quantum well layer and a p-type AlGaN layer) formed on the n-type GaN layer **2410***c*, and a p-type GaN layer **2410***e* formed on the second light-emitting layer **2410***d*. InN mole fraction of the second light-emitting layer **2410***d* is smaller than that of the first light-emitting layer **2410***b*. The above described layers are covered by a dielectric layer **2404**. Wirings **2461** and **2462** of the power supply side are respectively connected to p-type GaN layers **2410***a* and **2410***e*. A wiring **2475***c* of the ground side is connected to the n-type GaN layer **2410***c*.

In FIG. **32**, the second semiconductor element portion **2430** is made of GaAs-based semiconductor materials. In particular, an n-type $Al_xGa_{1-x}As$ layer **2430***a* is formed on the dielectric layer **2403** (via an electrode drawing layer **2431** and a contact metal layer **2432**), an n-type GaAs layer **2430***b* is formed on the n-type $Al_xGa_{1-x}As$ layer **2430***a*, and a third light-emitting layer **2430***c* (including an n-type $Al_yGa_{1-y}As$ cladding layer, an n-type $Al_zGa_{1-z}As$ active layer and a p-type $Al_tGa_{1-t}As$ cladding layer) is formed on the n-type GaAs layer **2430***b*. A p-type GaAs layer **2430***d* is formed on the third light-emitting layer **2430***c*. A wiring **2463** of the power-supply voltage side is connected to the p-type GaAs layer **2430***d* via the contact metal layer **2433**. An opening is formed on the dielectric layer **2404** covering the electrode drawing layer **2431**. Via the opening of the dielectric layer **2404**, the electrode drawing layer **2431** is electrically connected to a wiring **2475***a* through which the ground potential is applied via a wiring **2475***b* (FIG. **30**).

As shown in FIG. **30**, the wiring **2475** is a common wiring for the first semiconductor element portion **2410** and the second semiconductor element portion **2430**. A ground potential is applied to the wiring **2475** via a common electrode pad **2444**. Power-supply voltages are applied via the other three electrode pads **2443**, **2441** and **2442** to the wirings **2463**, **2461** and **2462**. The first light-emitting region of the first semiconductor element portion **2410** operates by applying the voltage between the electrode **2461** and the electrode **2475***c*. The second light-emitting region of the first semiconductor element portion **2410** is operated by applying the voltage between the electrode **2475***c* and the electrode **2462**. The third light-emitting region of the second semiconductor element portion **2430** is operated by applying the voltage between the electrode **2475***a* and the electrode **2463**. The examples and modifications of the respective semiconductor element portions described in the first embodiment can be applied to the fourth embodiment. Further, the modifications of the materials or the like described in the first embodiment can be applied to the fourth embodiment.

According to the fourth embodiment of the present invention, the light-emitting regions of the first semiconductor element portion **2410** and the light-emitting region of the second semiconductor element portion **2430** are connected in parallel with each other, and therefore the degrees of freedom in controlling of the respective light-emitting regions increase. Further, the voltages for operating the respective light-emitting regions can be reduced by connecting the light-emitting regions in parallel with each other.

FIGS. **33** through **38** show the modifications of the connection between the light-emitting regions of the first semiconductor element portion **2410** and the light-emitting region of the second semiconductor element portion **2430**. In each modification, the light-emitting regions of the first semiconductor element portion **2410** and the light-emitting region of the second semiconductor element portion **2430** are connected in parallel with each other. In each of the modifications shown in FIGS. **33** through **38**, it is possible to reverse the power-supply side and the ground side with respect to each other, and to reverse p-side and n-side (not shown) of the device with respect to each other.

FIG. **33** shows an example in which first and second light-emitting regions **2482***a* and **2481***a* of the first semiconductor element portion **2410** and a light-emitting region (not shown) of the second semiconductor element portion (not shown) are connected in parallel with each other. Power-supply wirings **2491***a* and **2492***a* and a ground wiring **2493***a* are connected to the light-emitting regions **2482***a* and **2481***a*. The power-supply wiring **2491***a* is formed on the periphery of the first light-emitting region **2482***a* of the first semiconductor element portion **2410** so that the power-supply wiring **2491***a* does not cover the first light-emitting region **2482***a*.

FIG. **34** shows another example in which first and second light-emitting regions **2482***b* and **2481***b* of the first semiconductor element portion **2410** and a light-emitting region (not shown) of the second semiconductor element portion (not shown) are connected in parallel with each other. Power-supply wirings **2491***b* and **2492***b* and a ground wiring **2493***b* are connected to the light-emitting regions **2482***b* and **2481***b*. The power-supply wiring **2491***b* is disposed on a position shifted from the first light-emitting region **2482***b* of the first semiconductor element portion **2410**. The power-supply wiring **2492***b* is disposed directly on the second light-emitting region **2481***b* of the first semiconductor element portion **2410**.

FIG. **35** shows still another example in which first and second light-emitting regions **2482***c* and **2481***c* of the first semiconductor element portion **2410** and a light-emitting region (not shown) of the second semiconductor element portion (not shown) are connected in parallel with each other. Power-supply wirings **2491***c* and **2492***c* and a ground wiring **2493***c* are connected to the light-emitting regions **2482***c* and **2481***c*. The power-supply wiring **2491***c* is disposed on a position shifted from the first light-emitting region **2482***c* of the first semiconductor element portion **2410**. The ground wiring **2493***c* extends to a position above the first light-emitting region **2482***c* of the first semiconductor element portion **2410**.

FIG. **36** shows yet another example in which first and second light-emitting regions **2482***d* and **2481***d* of the first semiconductor element portion **2410** and a light-emitting region (not shown) of the second semiconductor element portion (not shown) are connected in parallel with each other. The light-emitting regions **2482***d* and **2481***d* are not disposed adjacent to each other, but obliquely face each other. Power-supply wirings **2491***d* and **2492***d* and a ground wiring **2493***d* are connected to the light-emitting regions **2482***d* and **2481***d*. The power-supply wiring **2491***d* is disposed adjacent to the first light-emitting region **2482***d*, and is disposed on a position shifted from the first light-emitting region **2482***d* to the second light-emitting region **2481***d* side in such a manner that the power-supply wiring **2491***d* occupies a small space.

FIG. **37** shows further example in which first and second light-emitting regions **2482***e* and **2481***e* of the first semiconductor element portion **2410** and a light-emitting region (not shown) of the second semiconductor element portion (not shown) are connected in parallel with each other. The light-emitting regions **2482***e* and **2481***e* are not disposed adjacent to each other, but obliquely face each other. Power-supply wirings **2491***e* and **2492***e* and a ground wiring **2493***e* are connected to the light-emitting regions **2482***e* and **2481***e*. The power-supply wiring **2491***e* is disposed adjacent to the first light-emitting region **2482***e*, and is disposed on a position shifted from the first light-emitting region **2482***e* to the second light-emitting region **2481***e* side in such a manner that the power-supply wiring **2491***e* occupies a small space. A cutout portion is formed on the center portion of the first light-emitting region **2482***e*. With such an arrangement, the length of the pass of current can be increased, and therefore it becomes possible to prevent the concentration of the current on the contact portion.

FIG. **38** shows still further example in which first and second light-emitting regions **2482***f* and **2481***f* of the first semiconductor element portion **2410** and a light-emitting region (not shown) of the second semiconductor element portion (not shown) are connected in parallel with each other. The light-emitting regions **2482***f* and **2481***f* are not disposed adjacent to each other, but obliquely face each other. Power-supply wirings **2491***f* and **2492***f* and a ground wiring **2493***f* are connected to the light-emitting regions **2482***f* and **2481***f*. The power-supply wiring **2491***f* is disposed adjacent to the first light-emitting region **2482***f*, and is disposed on a position shifted from the first light-emitting region **2482***f* to the second light-emitting region **2481***f* side in such a manner that the power-supply wiring **2491***f* occupies a small space. The ground region **2493***f* extends outside the first light-emitting region **2482***f*.

Fifth Embodiment

FIG. **39** is a plan view schematically showing a composite semiconductor light-emitting device according to the fifth embodiment of the present invention. FIG. **40** is a sectional view taken along line **40-40** in FIG. **39**. FIG. **41** is a sectional view taken along line **41-41** in FIG. **39**. The fifth embodiment is different from the fourth embodiment in that a second semiconductor element portion **2630** made of GaAs-based semiconductor layers is bonded onto a first semiconductor element portion **2610** made of GaN-based semiconductor layers. The respective semiconductor element portions **2610** and **2630** can have the structures as descried in the first embodiment. Further, in the fifth embodiment, the respective light-emitting regions are electrically connected in parallel with each other. Modifications of the fourth embodiment are applicable to the fifth embodiment. As shown in FIG. **40**, the second semiconductor element portion **2630** is bonded onto a second dielectric layer **2440** on the first semiconductor element portion **2610**.

According to the fifth embodiment, the second semiconductor element portion **2630** is bonded onto the first semiconductor element portion **2610**, and therefore it is possible to obtain an advantage that the semiconductor element portions can be integrated in a small region, in addition to the advantages of the fourth embodiment. Therefore, the processing speed of the semiconductor element portions can be enhanced, and the yield of the manufacturing process can be enhanced.

Sixth Embodiment

FIG. **42** is a plan view schematically showing a composite semiconductor light-emitting device of the sixth embodiment of the present invention. The sixth embodiment is different from the fourth embodiment in that a second semiconductor element portion **3030** includes two light-emitting regions **3063** and **3064** having the same structures. If the light-emission efficiency of the light-emitting region of the second semiconductor element portion **3030** is lower than the light-emitting regions of the first semiconductor element portion **2410**, it is possible to provide a plurality of light-emitting regions **3063** and **3064** on the second semiconductor element portion **3030**, and to individually control the light-emitting regions to emit lights. With such an arrangement, it becomes easy to control the balance of the total amount of the lights emitted by the light-emitting regions of the first semiconductor element portion **2410** and the total amount of the lights emitted by the light-emitting regions of the second semiconductor element portion **3030**. Regarding the semiconductor structures of respective semiconductor element portions, it is possible to employ the semiconductor element portions as described in the first embodiment.

In FIG. **42**, the number of the light-emitting regions of the second semiconductor element portion **3030** is two, but can be appropriately varied as shown in FIG. **43**. In an example shown in FIG. **43**, four light-emitting regions **3163** through **3166** are formed on the second semiconductor element portion **3130**. The four light-emitting regions **3163** through **3166** are supplied with currents respectively via electrode pads **3143**, **3145**, **3146** and **3147**.

According to the sixth embodiment of the present invention, the second semiconductor element portion **3030** has a plurality of light-emitting regions (with respect to the first semiconductor element portion **2410** having the light-emitting regions), it becomes easy to control the balance of the total amount of the lights emitted by the light-emitting regions of the first semiconductor element portion **2410** and the total amount of the lights emitted by the light-emitting regions of the second semiconductor element portion **3030**.

Seventh Embodiment

FIG. **44** is a plan view schematically showing a composite semiconductor light-emitting device of the seventh embodiment of the present invention. FIG. **45** is a sectional view taken along line **45-45** in FIG. **44**. FIG. **46** is a sectional view taken along line **46-46** in FIG. **45**.

As shown in FIGS. **44** through **46**, the composite semiconductor light-emitting device of the seventh embodiment includes a substrate **3201** (of a driving integrated circuit board) on which a driving integrated circuit for driving the light-emitting elements is formed. On the substrate **3201**, a metal layer **3202** (having a function to reflect the light emitted by the light-emitting element and an electrical wiring function), a dielectric layer **3203** (for bonding a semiconductor film having a semiconductor element portion), first semiconductor element portions **3210** having light-emitting regions, second semiconductor element portions **3220** having light-emitting regions, a common electrode **3275** (for the light-emitting regions of the first and second semiconductor element portions **3210** and **3220**), contact regions **3276** that electrically connect the common electrode **3275** and the metal layer **3202**, wirings **3205** each of which connects two light-emitting regions of each first semiconductor element portion **3210**, wirings **3261** led from the first semiconductor element portions **3210**, wirings **3263** led from the second semiconductor element portions **3220**, input pads **3280** for inputs to the driving integrated circuit, and connection pads **3281** that connect the wirings **3261** and **3263** are formed.

The metal layer **3202** having a function as a common wiring is connected to a ground potential (not shown) provided in the driving integrated circuit or a ground-input pad (not shown) connectable directly from outside ground potential. Electrode contacts **3251** and **3253** are formed on the light-emitting elements of the first and second semiconductor element portions **3210** and **3220**. The electrode contacts **3251** and **3253** can be formed as transparent electrodes made of ITO (Indium Tin Oxide) or ZnO (Zinc Oxide). The electrode contacts **3251** and **3253** can be made of metal and formed to partially cover the light-emitting regions.

As shown in FIGS. **44** through **46**, each of the semiconductor element portions **3210** and **3220** has a plurality of light-emitting regions. The respective light-emitting regions of the second semiconductor element portion **3220** are configured and wired so that the light-emitting regions of the second semiconductor element portion **3220** can be controlled to emit lights individually and separately from the light-emitting regions of the first semiconductor element portion **3210**. The respective light-emitting regions can be arranged at constant pitches, or can be arranged at different pitches. The respective semiconductor element portions **3210** and **3220** can have the structures as described in the first embodiment, and can be modified as described in the first embodiment.

According to the seventh embodiment, each of the first and second semiconductor element portions **3210** and **3220** have a plurality of light-emitting regions that can be individually controlled to emit lights, and therefore it becomes possible to finely adjust the color and the emission property, and to integrate the light-emitting regions at high density.

Eight Embodiment

FIG. **47** is a plan view of a composite semiconductor light-emitting device according to the eight embodiment of the present invention. Different from the seventh embodiment, in the eight embodiment, a plurality of light-emitting regions of each semiconductor element portion are connected in parallel with each other.

In the eight embodiment shown in FIG. **47**, first semiconductor element portions **3610** and second semiconductor element portions **3620** are bonded onto a integrated circuit for driving light-emitting elements as described in the seventh embodiment. In FIG. **47**, on a substrate **3601** of an integrated circuit board (on which integrated circuits are formed), input pads **3680**, connection pads **3681** and **3682** that electrically connect wirings (connected to the light-emitting elements) and the integrated circuit, wirings **3642** and **3641** that electrically connect the connection pads and the electrodes, individual electrodes **3661** and **3662** (made of transparent electrodes) for the light-emitting regions of the first semiconductor element portions **3610**, and individual electrodes **3663**, **3664**, **3665** and **3666** (made of transparent electrodes) for the light-emitting regions of the second semiconductor element portions **3620** are formed. A common wiring **3675** is electrically connected to a ground potential. A metal layer **3602** is formed on the substrate **3601**, and the metal layer **3602** reflects the light emitted by the respective light-emitting regions.

According to the eight embodiment of the present invention, all light-emitting elements provided below the individual electrodes **3661** through **3664** are connected in parallel with each other. Therefore, it becomes easy to individually control the integrated light-emitting regions, and to finely control the balance of the lights emitted from the light-emitting regions. Although the first and second semiconductor element portions **3610** and **3620** are bonded onto the different regions on the substrate **3601** in FIG. **47**, it is also possible that the second semiconductor element portions **3620** are bonded onto the first semiconductor element portions **3610**. Although the second semiconductor element portion includes four light-emitting regions in FIG. **47**, the number of the light-emitting regions is not limited to four but can be appropriately varied. Further, the arrangement pitch and configuration can be appropriately modified.

Ninth Embodiment

FIG. **48** is a plan view schematically showing a composite semiconductor light-emitting device according to the ninth embodiment of the present invention. The ninth embodiment is different from the seventh and eight embodiments in that a first semiconductor element portion **3710** and a second semiconductor element portion **3730** are alternately disposed and bonded onto a driving integrated circuit board **3701**. The first semiconductor element portion **3710** includes two light-emitting regions individually controlled to emit the light. The second semiconductor element portion **3730** includes two light-emitting regions individually controlled to emit the light.

The semiconductor element portions described in the first embodiment can be employed in the ninth embodiment. To be more specific, on the driving integrated circuit board **3701** (on which integrated circuit is formed), a reflection layer **3702**, first semiconductor element portions **3710**, second semiconductor element portions **3730**, individual electrodes **3761** and **3762** of the light-emitting elements formed on the first semiconductor element portion **3701**, individual electrodes **3763** and **3764** of the light-emitting elements formed on the second semiconductor element portion **3702**, common wirings **3775**, and input pads **3780** for transmitting signal or supplying power to the driving integrated circuit. Connection pads **3781** and **3782** for connecting the individual wirings of the respective light-emitting elements and the driving integrated circuit are also formed on the driving integrated circuit board **3701**.

According to the ninth embodiment of the present invention, the first semiconductor element portion (i.e., the first semiconductor film) **3710** and the second semiconductor element portion **3730** (i.e., the second semiconductor film) are alternately disposed and bonded, and therefore the respective elements can be easily arranged.

In the above described embodiments, the lights emitted by the semiconductor element portions are descried as the visible lights. However, it is also possible to use a semiconductor element portion that emits infrared rays of different wavelengths, a semiconductor element portion that emits infrared rays and visible light at the same time, a semiconductor element portion that emits visible light and ultraviolet rays, or a semiconductor element portion that emits ultraviolet rays of different wavelengths, in combination with a semiconductor element portion that emits the light of another wavelength. In particular, it becomes possible to bond and integrate the semiconductor element portions respectively emitting the lights (for example, the semiconductor element portion that emits infrared rays and the semiconductor element portion that emits ultraviolet rays) whose wavelengths are so different that the light-emitting regions thereof can not be formed in one semiconductor element portion. With such an arrangement, the application range can be widened.

In the above described embodiments, the elements formed by layering the semiconductor layers are diodes. However, it is also possible to form semiconductor lasers, or other active elements such as transistors.

While the preferred embodiments of the present invention have been illustrated in detail, it should be apparent that modifications and improvements may be made to the invention without departing from the spirit and scope of the invention as described in the following claims.

What is claimed is:

1. A composite semiconductor light-emitting device comprising:

a first semiconductor element portion including a nitride-based semiconductor material, said first semiconductor element portion having a first semiconductor layered structure, said first semiconductor element portion including a plurality of light-emitting regions that emit lights of different wavelengths,

a second semiconductor element portion including a second semiconductor material different from said first semiconductor material, said second semiconductor element portion having a second semiconductor layered structure, said second semiconductor element portion including at least one light-emitting region that emits light whose wavelength is different from any of the lights emitted by said light-emitting regions, and

a metal wiring extending on at least said first semiconductor element portion to electrically connect said light-emitting regions of said first semiconductor element portion and said at least one light-emitting region of said second semiconductor element portion,

wherein said light-emitting regions of said first semiconductor element portion are composed of the same constituent material which is different from said at least one light-emitting region of said second semiconductor element portion.

2. The composite semiconductor light-emitting device according to claim **1**, wherein a plurality of said light-emitting regions formed on said first and second semiconductor element portions are connected in series with each other or in parallel with each other.

3. The composite semiconductor light-emitting device according to claim **1**, wherein the number of light-emitting regions of said first semiconductor element portion is greater than the number of light-emitting regions of said second semiconductor element portion.

4. The composite semiconductor light-emitting device according to claim **1**, wherein said first semiconductor element portion and said second semiconductor element portion are bonded to each other in the same region.

5. The composite semiconductor light-emitting device according to claim **4**, wherein said first semiconductor element portion is disposed on said second semiconductor element portion.

6. The composite semiconductor light-emitting device according to claim **4**, wherein said first semiconductor element portion is provided below said second semiconductor element portion.

7. The composite semiconductor light-emitting device according to claim **1**, further comprising a reflecting layer disposed below said first and second semiconductor element portions or between said first and second semiconductor element portions.

8. The composite semiconductor light-emitting device according to claim **1**, wherein said first and second semiconductor element portions are formed on a substrate on which a driving integrated circuit for controlling the light-emission of said light-emitting regions is formed.

9. The composite semiconductor light-emitting device according to claim **1**, wherein said first and second semiconductor element portions are formed of semiconductor thin-films separated from semiconductor substrates.

10. The composite semiconductor light-emitting device according to claim **1**, wherein said first and second semiconductor element portions are formed on different regions.

11. The composite semiconductor light-emitting device according to claim **1**, wherein a plurality of said first semiconductor element portions and a plurality of said second semiconductor element portions are provided, and

wherein an arrangement is provided for individually controlling light-emission of light-emitting regions of said first semiconductor element portions and said second semiconductor element portions.

12. The composite semiconductor light-emitting device according to claim **11**, further comprising an adjusting system for adjusting the color of the emitted light, by individually controlling light-emission of said light-emitting regions of said first semiconductor element portions and said second semiconductor element portions.

13. The composite semiconductor light-emitting device according to claim **1**, wherein a plurality of said first semiconductor element portions and a plurality of said second semiconductor element portions are provided, and

wherein said first semiconductor element portions and said second semiconductor element portions are alternately disposed.

14. A composite semiconductor light-emitting device comprising:

a first semiconductor element portion including a first semiconductor material, said first semiconductor element portion having a first semiconductor layered structure, said first semiconductor element portion including a plurality of light-emitting regions that emit lights of different wavelengths,

a second semiconductor element portion including a III-V compound semiconductor material which is different from said first semiconductor material, said second semiconductor element portion having a second semiconductor layered structure, said second semiconductor element portion including at least one light-emitting region that emits light whose wavelength is different from any of the lights emitted by said light-emitting regions, and

a metal wiring extending on at least said first semiconductor element portion to electrically connected said light-emitting regions of said first semiconductor element portion and said at least one light-emitting region of said second semiconductor element portion,

wherein said light-emitting regions of said first semiconductor element portion are composed of the same constituent material which is different from said at least one light-emitting region of said second semiconductor element portion.

15. The composite semiconductor light-emitting device according to claim **14**, wherein a plurality of said light-emitting regions formed on said first and second semiconductor element portions are connected in series with each other or in parallel with each other.

16. The composite semiconductor light-emitting device according to claim **14**, wherein the number of light-emitting regions of said first semiconductor element portion is greater than the number of light-emitting regions of said second semiconductor element portion.

17. The composite semiconductor light-emitting device according to claim **14**, wherein said first semiconductor element portion and said second semiconductor element portion are bonded to each other in the same region.

18. The composite semiconductor light-emitting device according to claim **17**, wherein said first semiconductor element portion is disposed on said second semiconductor element portion.

19. The composite semiconductor light-emitting device according to claim **17**, wherein said first semiconductor element portion is provided below said second semiconductor element portion.

20. The composite semiconductor light-emitting device according to claim **14**, further comprising a reflecting layer disposed below said first and second semiconductor element portions or between said first and second semiconductor element portions.

21. The composite semiconductor light-emitting device according to claim **14**, wherein said first and second semiconductor element portions are formed on a substrate on which a driving integrated circuit for controlling the light-emission of said light-emitting regions is formed.

22. The composite semiconductor light-emitting device according to claim **14**, wherein said first and second semiconductor element portions are formed of semiconductor thin-films separated from semiconductor substrates.

23. The composite semiconductor light-emitting device according to claim **14**, wherein said first semiconductor element portion is formed of nitride-based semiconductor material.

24. The composite semiconductor light-emitting device according to claim **14**, wherein said first and second semiconductor element portions are formed on different regions.

25. The composite semiconductor light-emitting device according to claim **14**, wherein a plurality of said first semiconductor element portions and a plurality of said second semiconductor element portions are provided, and

wherein an arrangement is provided for individually controlling light-emission of light-emitting regions of said first semiconductor element portions and said second semiconductor element portions.

26. The composite semiconductor light-emitting device according to claim **25**, further comprising an adjusting system for adjusting the color of the emitted light, by individually controlling light-emission of said light-emitting regions of said first semiconductor element portions and said second semiconductor element portions.

27. The composite semiconductor light-emitting device according to claim **14**, wherein a plurality of said first semiconductor element portions and a plurality of said second semiconductor element portions are provided, and

wherein said first semiconductor element portions and said second semiconductor element portions are alternately disposed.

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